State of Louisiana
Coastal Protection and Restoration Authority

2012 Operations, Maintenance, and Monitoring Report

for

Fritchie Marsh Restoration (PO-06)

State Project Number PO-06
Priority Project List 2

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St. Tammany Parish

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For
Fritchie Marsh Restoration (PO-06)

Table of Contents

Preface

This report includes monitoring data collected from 1996 to 2011, and Annual Maintenance Inspections through June 2012.

The 2012 Operations, Maintenance, & Monitoring (OM&M) Report is the third in a series that includes monitoring data and analyses presented previously in the 2004 and 2007 OM&M Reports, plus additional project-specific and CRMS data collected since 2007. Please refer to the 2004 and 2007 OM&M Reports at the following website:
http://sonris.com/direct.asp?path=/sundown/cart_prod/cart_bms_avail_documents_f

I. Introduction

The Fritchie Marsh Restoration (PO-06) project encompasses an area of intermediate to brackish marsh approximately 3 miles southeast of Slidell, Louisiana. The 6,291-ac (2,546-ha) area is bound by US Hwy 190 to the north, US Hwy 90 to the south and east, and LA Hwy 433 to the west and south (Figure 1) and is part of the Big Branch Marsh Wildlife Management Refuge complex. The project is sponsored by the USDA-Natural Resources Conservation Service (NRCS) and the Coastal Protection and Restoration Authority of Louisiana (CPRA) on Project Priority List 2 of the Coastal Wetlands Planning, Protection, and Restoration Act (CWPPRA).

From 1956 to 1984, 2,260-ac (915-ha) of emergent marsh within the project area were converted to open water, with the greatest loss occurring in the northern project area. This loss reflected a pattern of marsh deterioration from north to south due to a reduction of freshwater and sediment input into the northern part of the project area. Natural hydrologic patterns were disrupted by the construction of the perimeter highways. These embankments isolated the marsh from the West Pearl River and restricted the inflow of freshwater, nutrients, and sediment, while saltwater from Lake Pontchartrain continued to enter the system through the W-14 canal and Little Lagoon during high tides and strong winds. As a result, the project area converted from a predominantly fresh marsh in 1956 to a predominantly brackish marsh by 1990.

The objective of the Fritchie Marsh Restoration project was to reduce marsh loss by restoring more natural hydrologic conditions in the project area through management of available freshwater. Specific objectives were (1) to increase freshwater flow and promote water exchange into the area from the West Pearl River by enlarging the culvert at U.S. Highway 90 and dredging portions of Salt Bayou and (2) to increase freshwater flow into the northern portion of the project area by diverting flow from the W-14 canal. The Fritchie Marsh Restoration project was constructed in one phase beginning in October 2000 and ending in March 2001. The project has a 20-year economic life which began in March 2001.

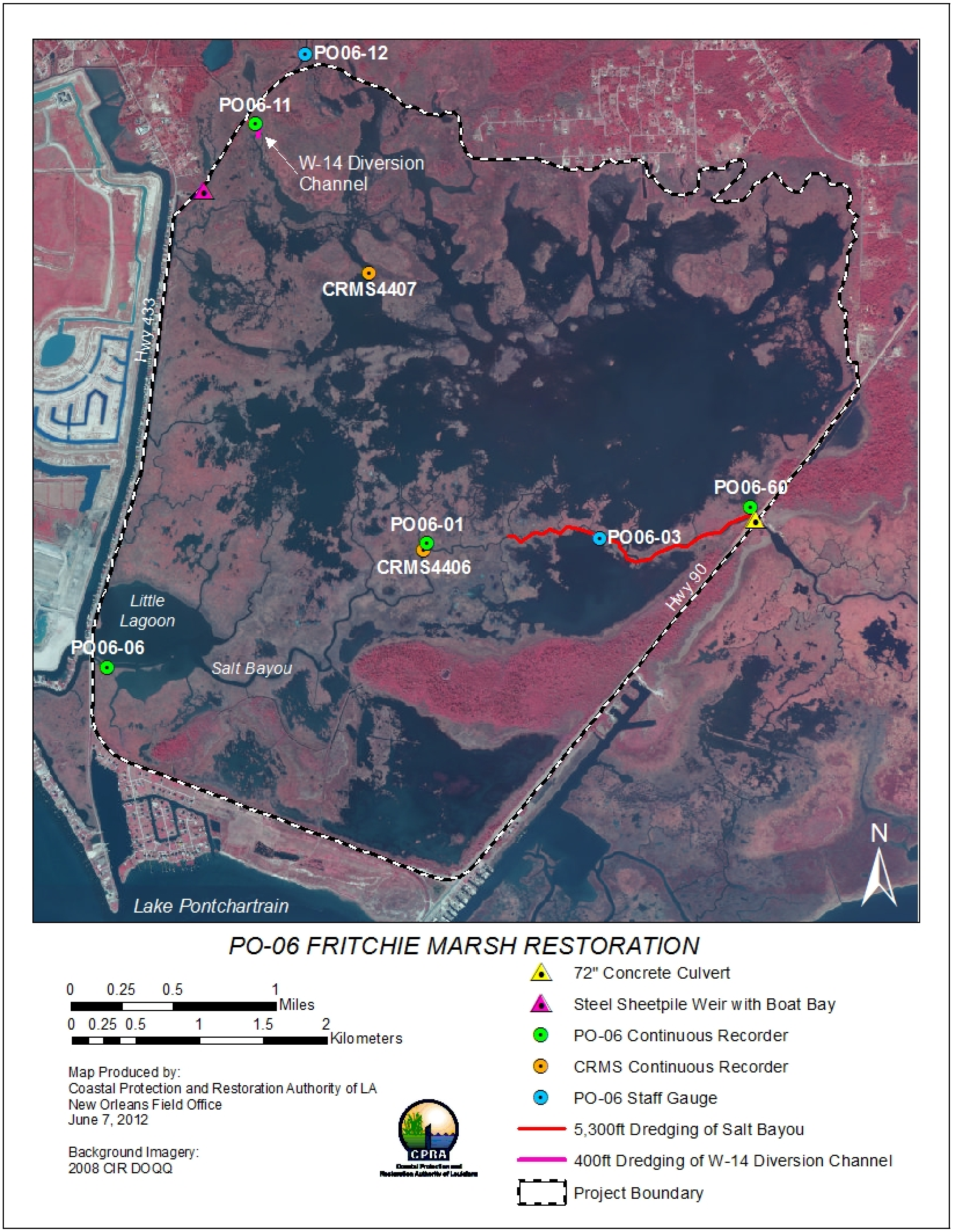

Figure 1. Fritchie Marsh Restoration (PO-06) project boundary, construction features, continuous recorder locations, and CRMS site locations.

The principal project features included:

- Installation (jack and bore) of a 72-inch diameter by 136-foot long concrete culvert under U.S. Highway 90, rock riprap lining of the Salt Bayou channel bottom and pipe outlets, and installation of 308 linear feet of sheet piling to form a bulkhead.
- Installation of a weir in the W-14 canal. The weir consists of 108 linear feet of sheet pile with a 20-foot wide boat bay.
- Dredging of approximately 400 linear feet of the W-14 diversion channel and 5300 linear feet of the Salt Bayou channel.

II. Maintenance Activity

a. Project Feature Inspection Procedures

The purpose of the annual inspection of the Fritchie Marsh Restoration project is to evaluate the constructed project features, to identify any deficiencies, and to prepare a report detailing the condition of project features and recommended corrective actions, if necessary. Should it be determined that corrective actions are needed, CPRA shall provide a detailed cost estimate for engineering, design, supervision, inspection, and construction contingencies, and an assessment of the urgency of such repairs (CPRA 2002). The annual inspection report also contains a summary of maintenance projects and an estimated projected budget for the upcoming three (3) years for operation, maintenance and rehabilitation. The three (3) year projected operation and maintenance budget is shown in Appendix B.

An inspection of the Fritchie Marsh Restoration Project (PO-06) was held on June 21, 2012, by Barry Richard (CPRA), Warren Blanchard (NRCS), and Alton James (NRCS). Access to Salt Bayou was not available due to siltation. Field inspection notes are shown in Appendix C.

b. Inspection Results

<u>Hwy 90 Culvert and Stone Revetment</u>

There is no change in this structure from the previous inspection. The bank scour reported in previous inspection reports is still of concern; however, it is well vegetated (Appendix A, Photos #1 and 2).

<u>Salt Bayou Dredging</u>

A detailed inspection of Salt Bayou was not performed due to access issues. A considerable portion of the bayou is now inaccessible to conventional vessels due to siltation. It was stated in previous inspection reports that there would be an evaluation of the need for maintenance dredging and bank restoration along Salt Bayou. After reviewing the goals of the project, it was determined that this will not be necessary. The main goal of the project is to divert and retain fresh water into the project area. While a good portion of Salt Bayou has silted in, there is a stretch near the culverts that has remained deep and continues to allow fresh water to enter the project area. As fresh water reaches the silted-in portion of the bayou, it is actually redirected into the adjacent marsh through several breaches in the bank. Therefore, the goal of diverting fresh water into the project area is being achieved.

W-14 Weir

There was no visible damage to this structure and it is operating as designed (Appendix A, Photo #3).

W-14 Diversion Channel Dredging

There is no visible change to this feature. It is diverting water from the north as designed (Appendix A, Photo #4).

c. Maintenance Recommendations

i. Immediate/ Emergency Repairs

No immediate repairs are needed.

i. Programmatic/ Routine Repairs

No routine repairs are needed.

III. Operation Activity

a. Operation Plan

This project requires no operations activity; therefore, no operation plan has been generated.

b. Actual Operations

This project requires no operations activity; therefore, no structure operations have been conducted.

IV. Monitoring Activity

Pursuant to a CWPPRA Task Force decision on August 14, 2003 to adopt the Coastwide Reference Monitoring System-*Wetlands* (CRMS-*Wetlands*) for CWPPRA, updates were made to the PO-06 Monitoring Plan to merge it with CRMS-*Wetlands* and provide more useful information for modeling efforts and future project planning while maintaining the monitoring mandates of the Breaux Act. There are two CRMS sites located in the PO-06 project area, CRMS4406 and CRMS4407, which will be used to supplement existing project-specific data to further evaluate the effectiveness of the project.

a. Monitoring Goals

The objective of the Fritchie Marsh Restoration Project is to restore more natural hydrologic conditions in the project area resulting in the protection of the existing marsh.

The following goals will contribute to the evaluation of the above objective:

1. Decrease rate of marsh loss.
2. Increase freshwater flow and promote water exchange into the area from West Pearl River by enlarging the culvert at US Highway 90 and by dredging portions of Salt Bayou.
3. Increase freshwater flow into the northern project area by diverting flow from the W-14 canal.
4. Document species composition and relative abundance of vegetation to evaluate change over time.

b. Monitoring Elements

Photography

Color-infrared aerial photography (1:12,000 scale) has been obtained of the project area and reference area. Pre-construction photography was obtained in 1996 and 2000, and post-construction photography was obtained in 2004 and 2010. One final round of photography will be obtained in 2019. The acquired photography was geo-rectified, photo-interpreted, and analyzed with GIS using standard operating procedures documented in Steyer et al. (1995, revised 2000). Although the original monitoring plan stated that habitat analyses would be conducted, these were changed to land/water analyses upon the implementation of CRMS in 2003. The implementation plan of CRMS included a review of monitoring efforts on currently constructed CWPPRA projects, which concluded that habitat analyses on these projects should be converted to land/water analyses.

Salinity

Salinity was sampled hourly using continuous recorders at four locations within the project area (Figure 1) using methods described in Folse et al. (2008, revised 2012). Three continuous recorders were placed in Salt Bayou and one was placed in the marsh near the diversion of the W-14 canal. The continuous recorder at each site was mounted on a wooden post in open water with sufficient water depths to inundate the recorder year round. Each continuous recorder station was serviced approximately once every month to clean and calibrate the recorder and to download the data. During processing, the data were examined for accuracy and loaded to the CPRA database, and are available for download from the CRMS website (http://www.lacoast.gov/crms2). Salinity monitoring occurred at these sites during the pre-construction period from 1997 to 2000 and during the post-construction period from 2001 to mid-2005. Hourly salinity and water level data have since been recorded at two CRMS sites within the project area, CRMS4406 and CRMS4407, from November 2007 to the present. CRMS4406 is located along Salt Bayou near the former site of project-specific station, PO06-01. CRMS4407 is located within the northern half of the project area.

Water Level

Water levels were measured hourly using the same continuous recorders that were used for salinity monitoring (Figure 1). A staff gauge was installed next to each continuous recorder to compare recorded water levels to a known datum (NAVD88). Water level data (ft NAVD88) were collected during the pre-construction period from 1997 to 2000 and during the post-construction period from 2001 to mid-2005. Hourly water level data (ft NAVD88) have since been recorded at two CRMS sites within the project area, CRMS4406 and CRMS4407, from November 2007 to the present.

Water Flow

To monitor the increased flow of water into the project area at the Salt Bayou culvert and at the diversion at the W-14 canal, hourly current meter data were collected by LSU at five stations near the same locations where continuous recorders were present. Flow volume estimates at each station were made using recorded current data, channel cross sections, and water level data from the associated continuous recorder station. The meters were deployed for a one year period prior to construction (October 1998 to January 2000) and for the same duration after construction (December 2001 to December 2002). Unfortunately, the flow data has been determined by CPRA to be unsuitable for analysis. A meeting was held in May 2005 in which representatives from LSU and CPRA, as well as an expert hydrologist from USGS, were present. Several anomalies in the data were discussed but were unable to be sufficiently resolved. This determination was based on several factors including unreasonably high observed flow rates during some periods, inability to confirm cross-sectional area calculations of the channel, and too many zero values in the post-construction data. According to the USGS expert, further problems were due to improper meter type and placement, as well as the absence of developing adequate index/mean velocity relationships. These relationships must be developed from flux measurements that change over time and under different flow conditions. The problems cannot be repaired through re-processing because the proper ground truth data were not collected.

Vegetation

Species composition, percent cover, and relative abundance were evaluated within 2-m x 2-m plots using a modified Braun-Blanquet sampling method (Mueller-Dombois and Ellenberg 1974, Folse et al. 2008, revised 2012) in 1997 and 2000 (pre-construction), and in 2004, 2007, and 2010 (post-construction). Vegetation surveys will be conducted again in 2013, 2016, and 2019. During the first survey in 1997, 25 plots were sampled; however, four additional plots were established in 1999 for a total of 29 plots. In subsequent sampling years, any plot that converted to open water was re-established within the nearest landmass and renamed by adding an 'A' to the end of the station name (i.e., PO06-23 was re-established as PO06-23A). This was to ensure that we would continue to characterize the vegetation throughout the project area, despite the loss of sampling plots. Nine of the original plots have converted to open water since sampling began.

Emergent marsh vegetation has also been sampled annually at the two CRMS sites within the project area (CRMS4406 and CRMS4407) since 2007. At each CRMS site, ten 2-m x 2-m sampling plots were randomly located along a 288-m transect and were sampled using the same method described above. Percent coverage data from the PO-06 stations and CRMS stations were summarized according to the Floristic Quality Index (FQI) method utilized by CRMS (Cretini et al. 2011), where cover is qualified by scoring species according to their tolerance to disturbance and stability within specific habitat types.

CRMS Supplemental

Additional data were collected at CRMS-*Wetlands* stations, which can be used as supporting or contextual information for this project. Data types collected at CRMS sites include hydrologic, emergent vegetation, physical soil characteristics, discrete porewater salinity, marsh surface elevation change, vertical accretion, and land:water analysis of the 1-km^2 area encompassing the station (Folse et al. 2008, revised 2012). For this report, hydrologic data from the two CRMS sites inside the project area (CRMS4406 and CRMS4407) were used to assess project goals in years after project-specific hydrologic monitoring had ended.

c. Preliminary Monitoring Results and Discussion

Land/Water Analysis

One of the specific monitoring goals for the Fritchie Marsh Restoration project was to reduce the rate of marsh loss within the project area. To evaluate land changes within the project and reference areas, land/water analyses were conducted in 1996, 2000, 2004, and 2010 (Figures 2, 3, 4, and 5). The pre-construction loss rate for the 1996 to 2000 period was 31.5 ac/yr (Table 1). In the years immediately after construction (2000 to 2004), the acreage of land within the project area remained stable and showed a gain of 13 acres (3.3 ac/yr). However, a significant loss rate of 152.7 ac/yr occurred in the project area from 2004 to 2010, due mainly to Hurricane Katrina as further discussed below. To compare changes within the project and reference areas, land acreage for each sample

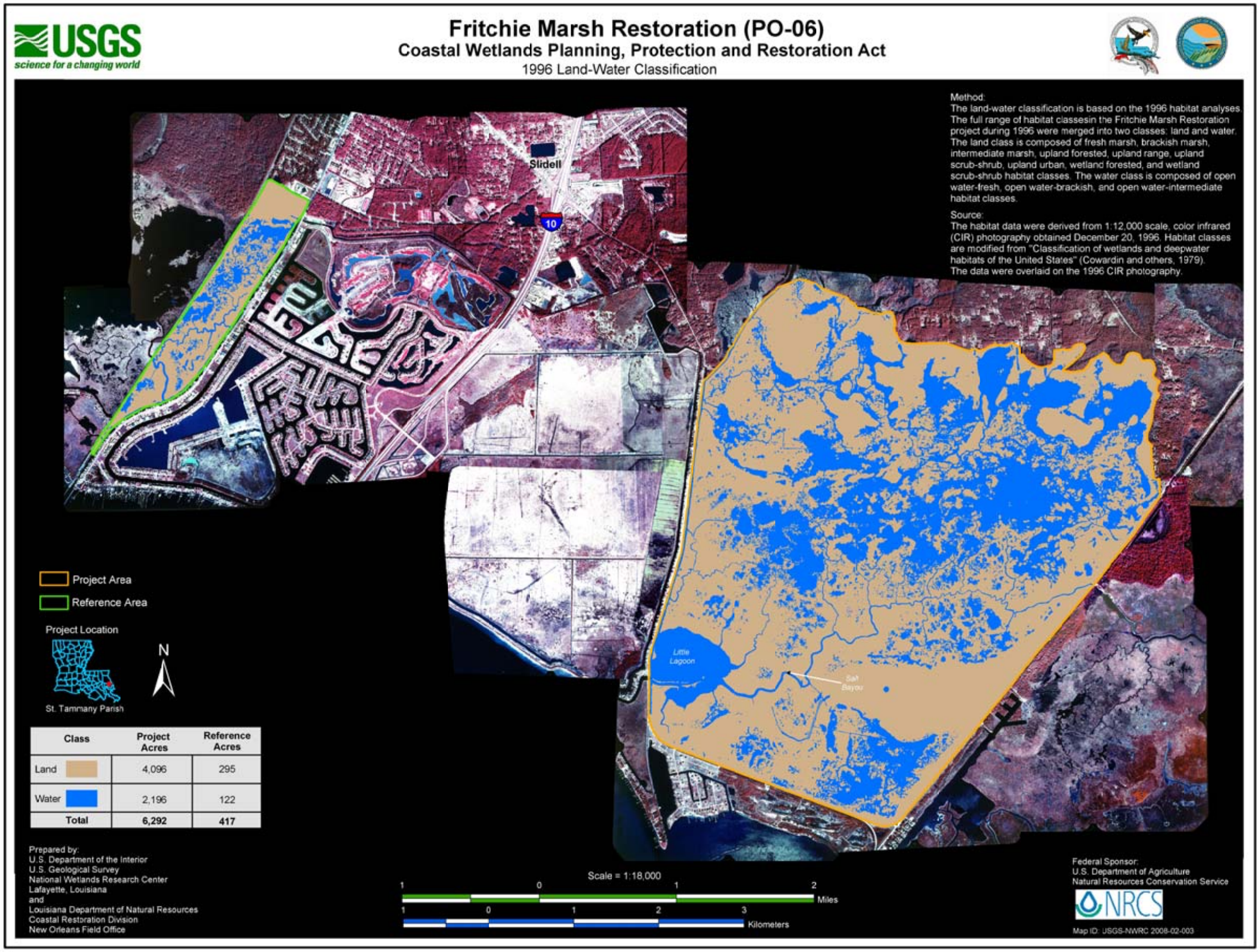

Figure 2. 1996 land/water analysis of the Fritchie Marsh Restoration (PO-06) project area.

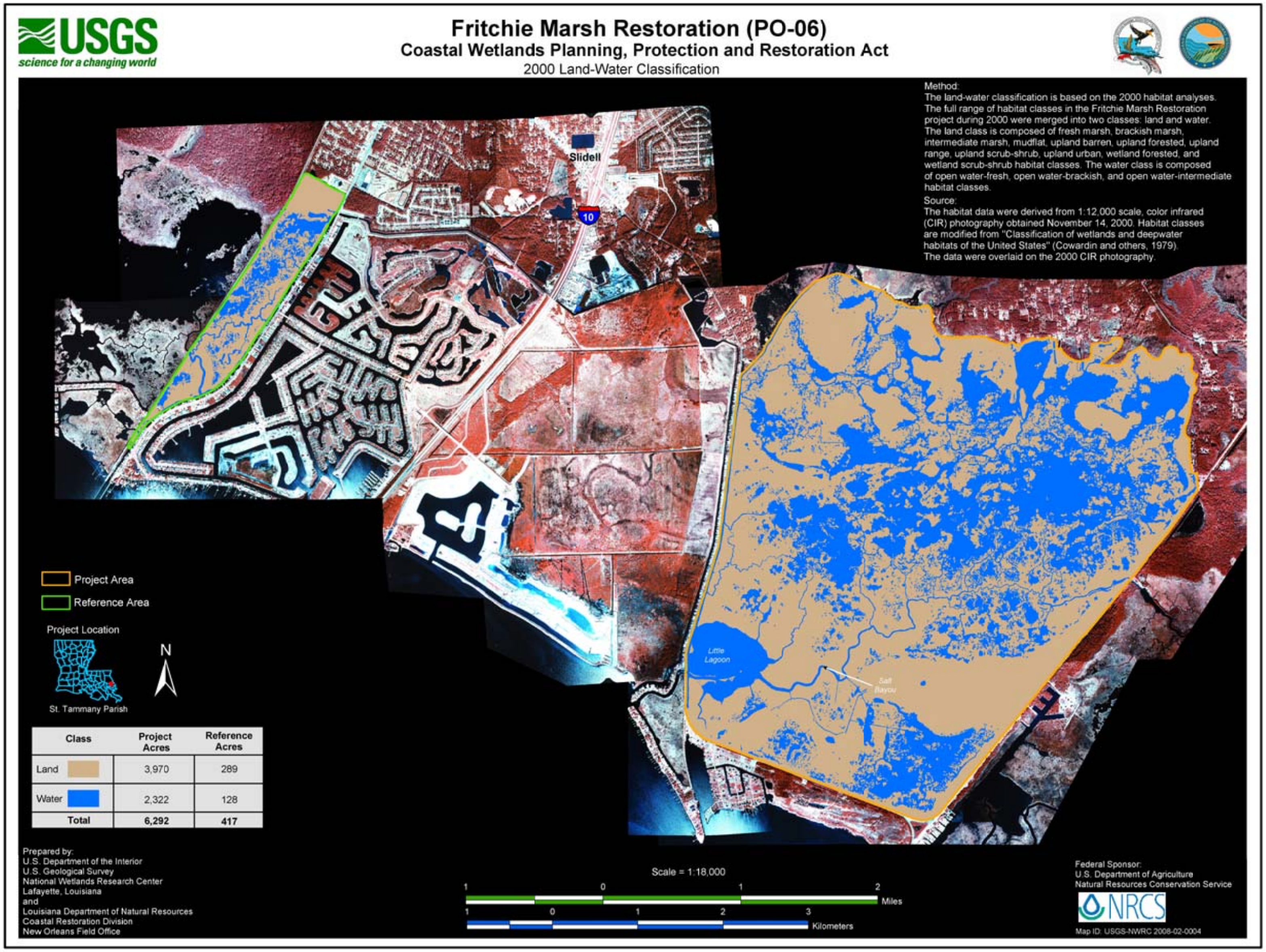

Figure 3. 2000 land/water analysis of the Fritchie Marsh Restoration (PO-06) project area.

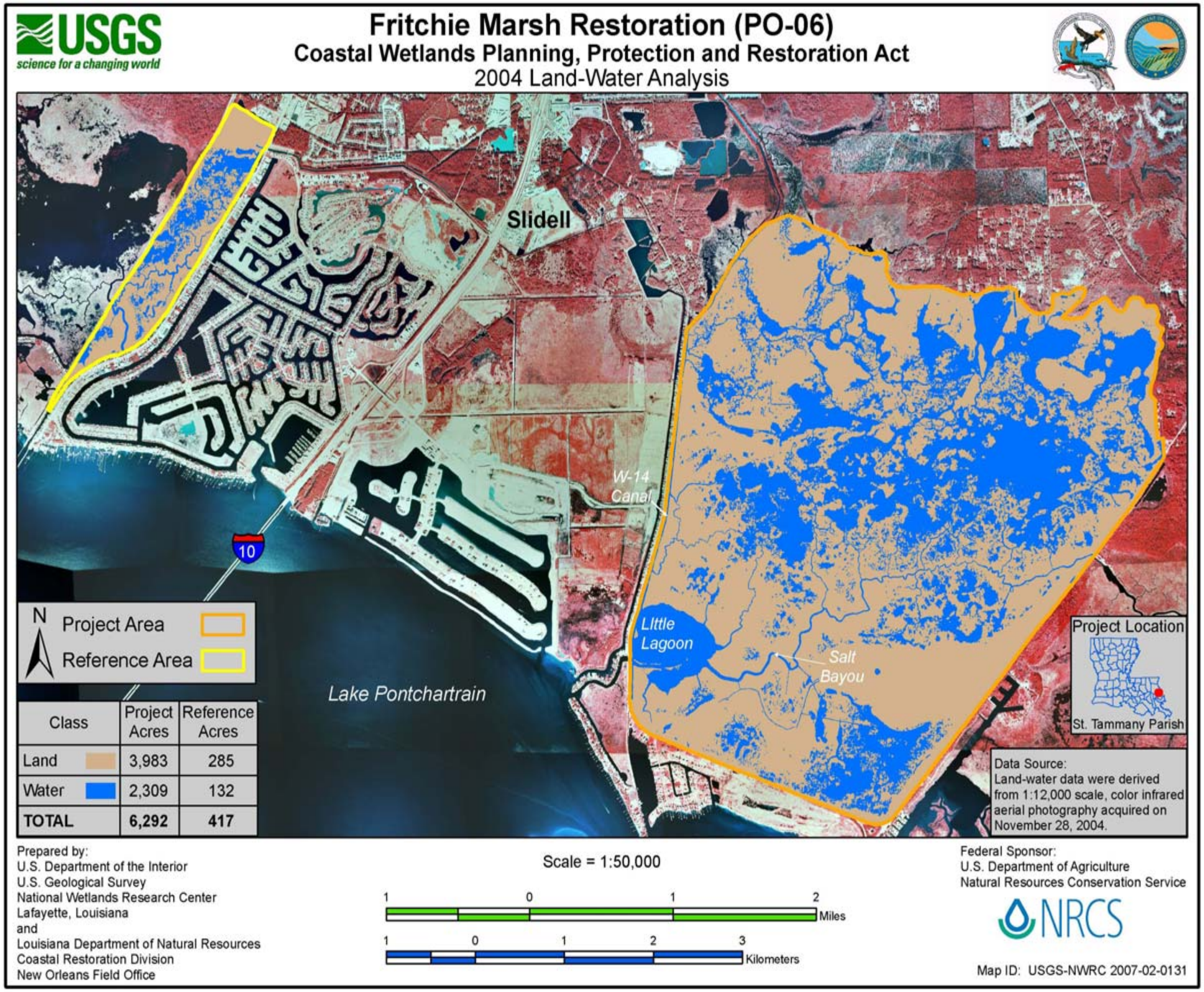

Figure 4. 2004 land/water analysis of the Fritchie Marsh Restoration (PO-06) project area.

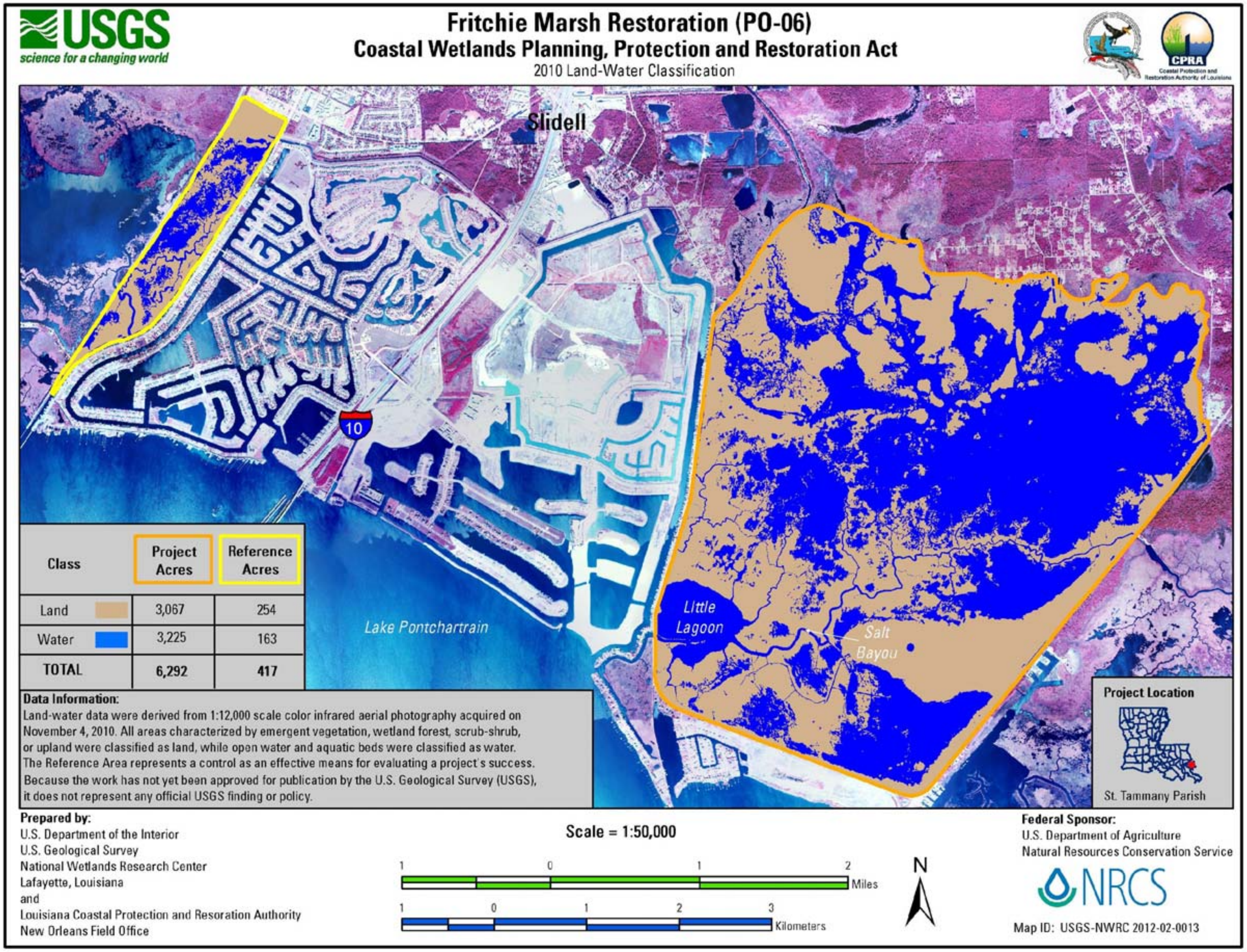

Figure 5. 2010 land/water analysis of the Fritchie Marsh Restoration (PO-06) project area.

Table 1. Land/water analysis summary for the Fritchie Marsh Restoration (PO-06) project area and reference area from 1996 to 2010.

Year Range	Project			Reference		
	Land Change (acres)	% of Total Acreage Gained/Lost	Loss/Gain Rate (Acres/yr)	Land Change (acres)	% of Total Acreage Gained/Lost	Loss/Gain Rate (Acres/yr)
1996-2000 (Pre-construction)	-126	-2.0%	-31.5/yr	-6	-1.4%	-1.5/yr
2000-2004	+13	+0.2%	+3.3/yr	-4	-1.0%	-1/yr
2004-2010	-916	-14.6%	-152.7/yr	-31	-7.4%	-5.2/yr
Overall (1996-2010)	**-1,029**	**-16.4%**	**-73.5/yr**	**-41**	**-9.8%**	**-2.9/yr**

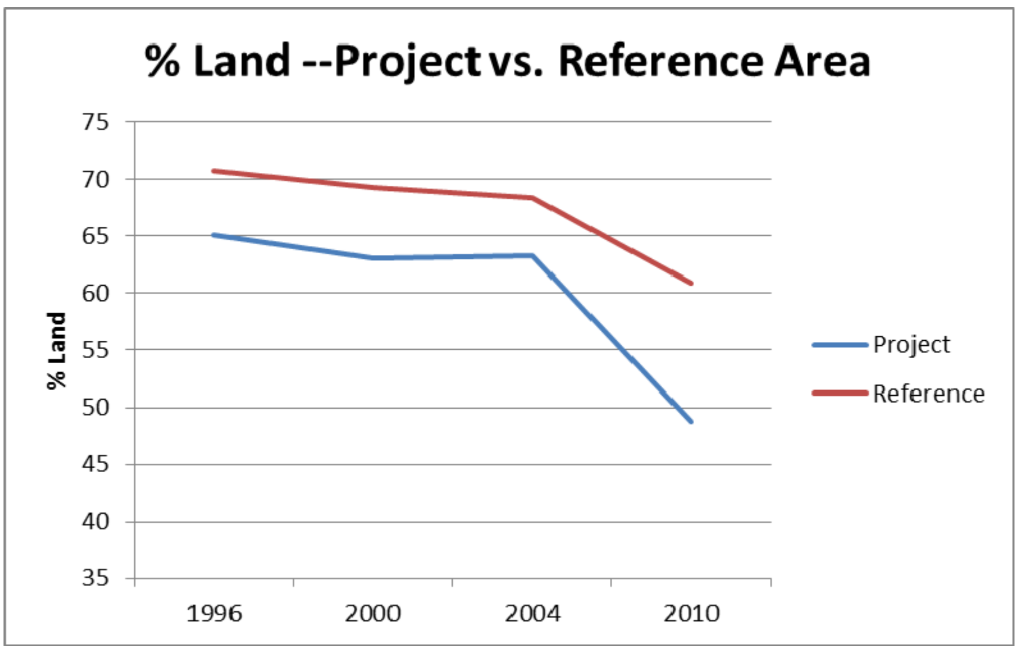

Figure 6. Percentage of land within the Fritchie Marsh Restoration (PO-06) project and reference areas for the years 1996, 2000, 2004, and 2010.

year was expressed as a percent of total acreage (Figure 6). Changes in % land within the project and reference areas were proportionally similar from 1996 to 2004. From 2004 to 2010, however, the project area experienced a relatively greater decrease in % land than the reference area.

Field observations made within the project area directly after Hurricane Katrina in 2005 indicated significant land loss within the project area as a result of the storm. In order to determine the effects of Hurricane Katrina, USGS conducted an analysis comparing 2004 and 2005 Landsat 5 satellite imagery (Figure 7). This analysis showed a loss of 1,037 acres of land between 2004 and 2005, or approximately 22.5% of the pre-storm land acreage. Likewise, the current analysis shows a 23.0% loss of the 2004 land acreage in 2010. The USGS analysis implies that the majority of this land loss that occurred between 2004 and 2010 was a direct result of Hurricane Katrina. Additionally, land/water analyses of the two CRMS sites in the project area in 2005 (post-Katrina) and 2008, show that land acreage in the project area was stable in the post-Katrina period. Percentage land within the 1-km^2 area at each CRMS site actually showed a gain of 1.2% at CRMS4406 and 3.2% at CRMS4407 (Figure 8).

The post-Katrina imagery shows that a significant portion of the land loss occurred within the northeastern quadrant of the project area, which contained the most fragmented marsh before the storm. While land loss was also accelerated in the reference area after Hurricane Katrina, it was of lesser magnitude than the project area. The highly fragmented areas of marsh within the project area were likely more vulnerable to storm effects than the reference area. Because of the extreme effects of Hurricane Katrina, it is difficult to draw definite conclusions on project effectiveness from the land/water analyses. The change in the loss/gain rate from -31.5 ac/yr before construction to +3.3 ac/yr from 2000 to 2004 indicates that the project may have been having a positive effect before Hurricane Katrina; however a decreased loss rate was also seen within the reference area during this period. The final land/water analysis of the project area in 2019, as well as additional CRMS analyses, will provide more information on whether the remaining land acreage in the project continues to remain stable.

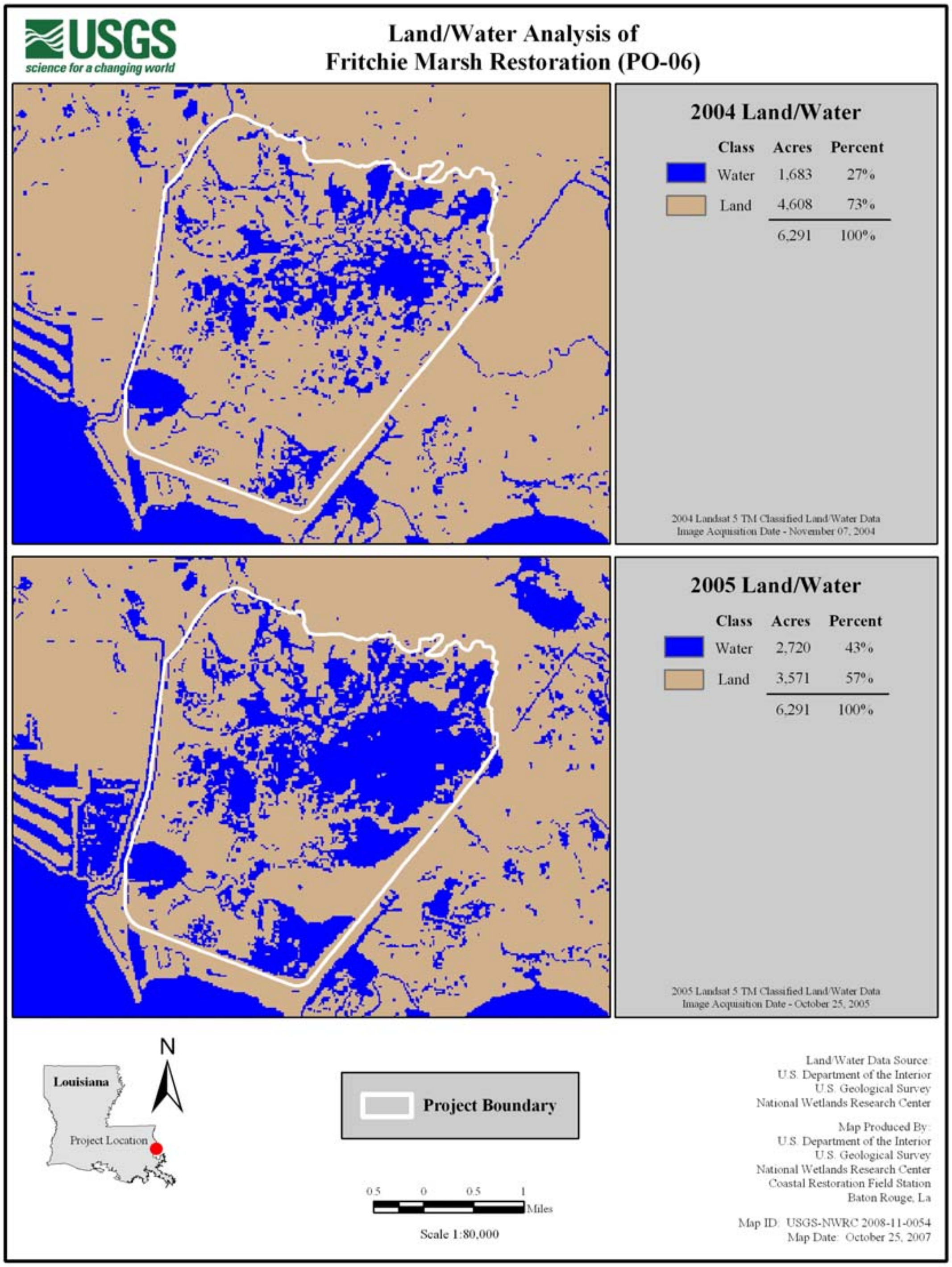

Figure 7. 2004 and 2005 land/water comparison of the Fritchie Marsh Restoration (PO-06) project area using Landsat 5 satellite imagery. The 2005 imagery was acquired two months after the passage of Hurricane Katrina.

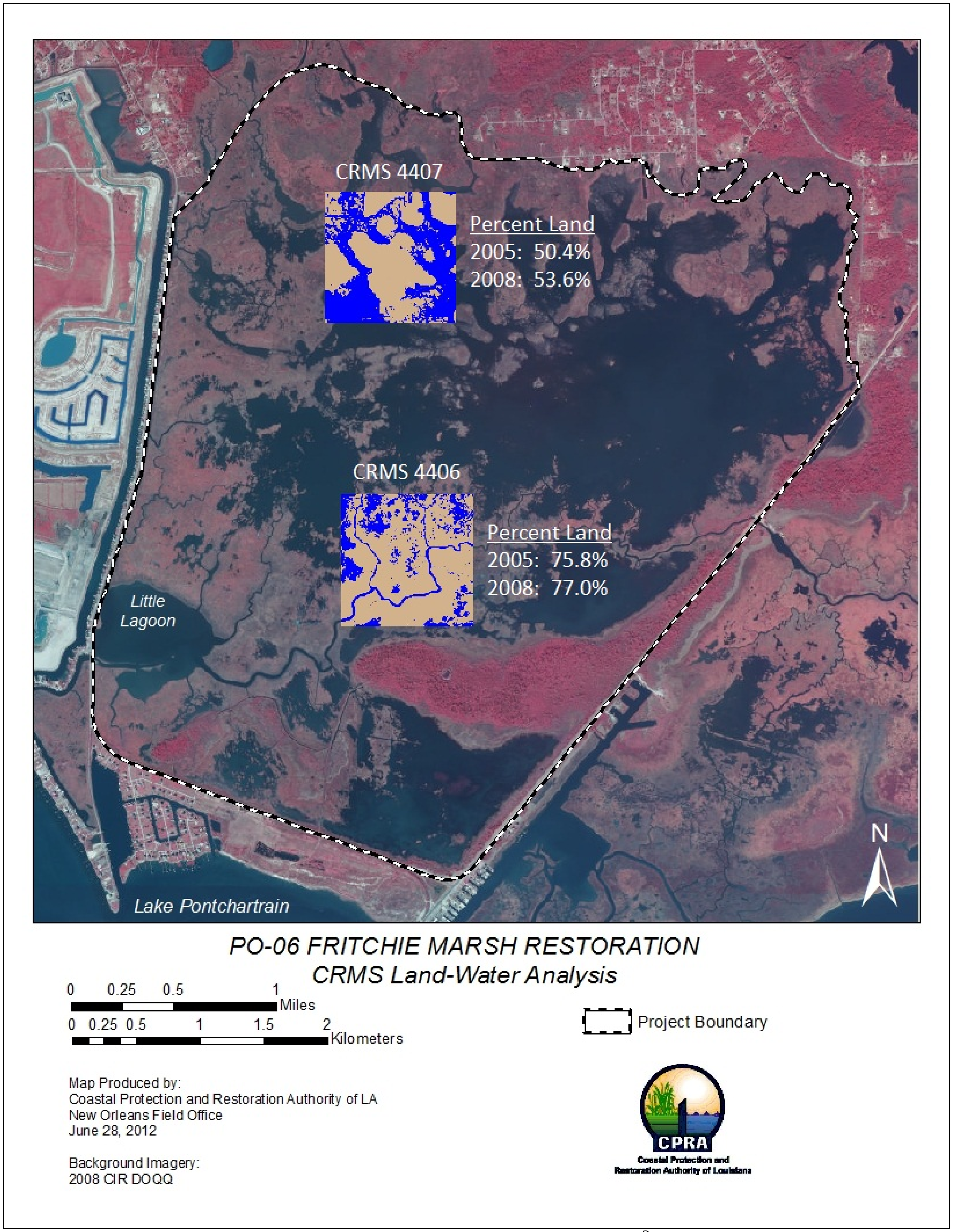

Figure 8. Land water results for two CRMS sites (1-km^2) within the Fritchie Marsh Restoration (PO-06) project area in 2005 and 2008.

Salinity and Water Level

Two main goals of the Fritchie Marsh Restoration project were to increase freshwater flow into the northern project area from the W-14 Canal and into the eastern project area through the Hwy 90 culvert. To determine the effects of project features on hydrologic conditions, hourly salinity and water level data were collected at the following continuous recorder stations (Figure 1):

Station	Data collection period
PO06-01	2/1996 – 6/2005
PO06-03*	6/1997 – 3/1999
PO06-06	6/1997 – 6/2005
PO06-11	6/1997 – 6/2005
PO06-60*	3/1999 – 6/2005
CRMS4406	11/2007 – present
CRMS4407	11/2007 – present

*The continuous recorder at PO06-03 was removed because the water level dropped below the sonde sensor during normal low-water periods. The replacement station, PO06-60 was installed in deeper water closer to the Hwy. 90 culvert.

Discrete staff gauge readings were also recorded each month from March 1998 to June 2005 at the four PO-06 continuous recorder stations and at two additional staff gauge locations (Figure 1). Monthly mean salinity and water level at the different recorder stations displayed similar responses to seasonal influences and storm events (Figures 9 and 10). Salinity was generally lowest near the Hwy 90 culvert (PO06-60) and highest on the western side of the project area where exchange with Lake Pontchartrain occurs (PO06-06). Salinity and water level spikes resulted from several tropical events including Tropical Storm Frances/Hurricane Georges in 1998, and Hurricanes Gustave and Ike in 2008, but were generally not prolonged. A prolonged drought, however, occurred from late 1999 through late 2000 with all stations experiencing elevated salinities during most of this period. The end of the drought occurred just before the completion of construction in March 2001.

Continuous salinity and water level data through 2005 were analyzed using a 2 X 4 BACI factorial analysis of variance (ANOVA) in which an interaction between the main effects is tested for statistical significance (Stewart-Oaten et al. 1986, Underwood 1994, Smith 2002). The main effects were defined as *period* (pre-construction vs. post-construction) and *location* (station ID). The construction date used to define the pre- vs post-construction periods was March 1, 2001. A standard BACI analysis uses a 2 X 2 factorial treatment structure, with the individual stations representing spatial replication within the two levels of the Control-Impact (CI) treatment (i.e. reference area and project area). However, this project was designed without reference stations, so the four stations were compared with each other using *location* as a random effect and with no single station designated purely as a reference station. The only additional assumption needed is that if the project had an impact it would apply unevenly among the four stations.

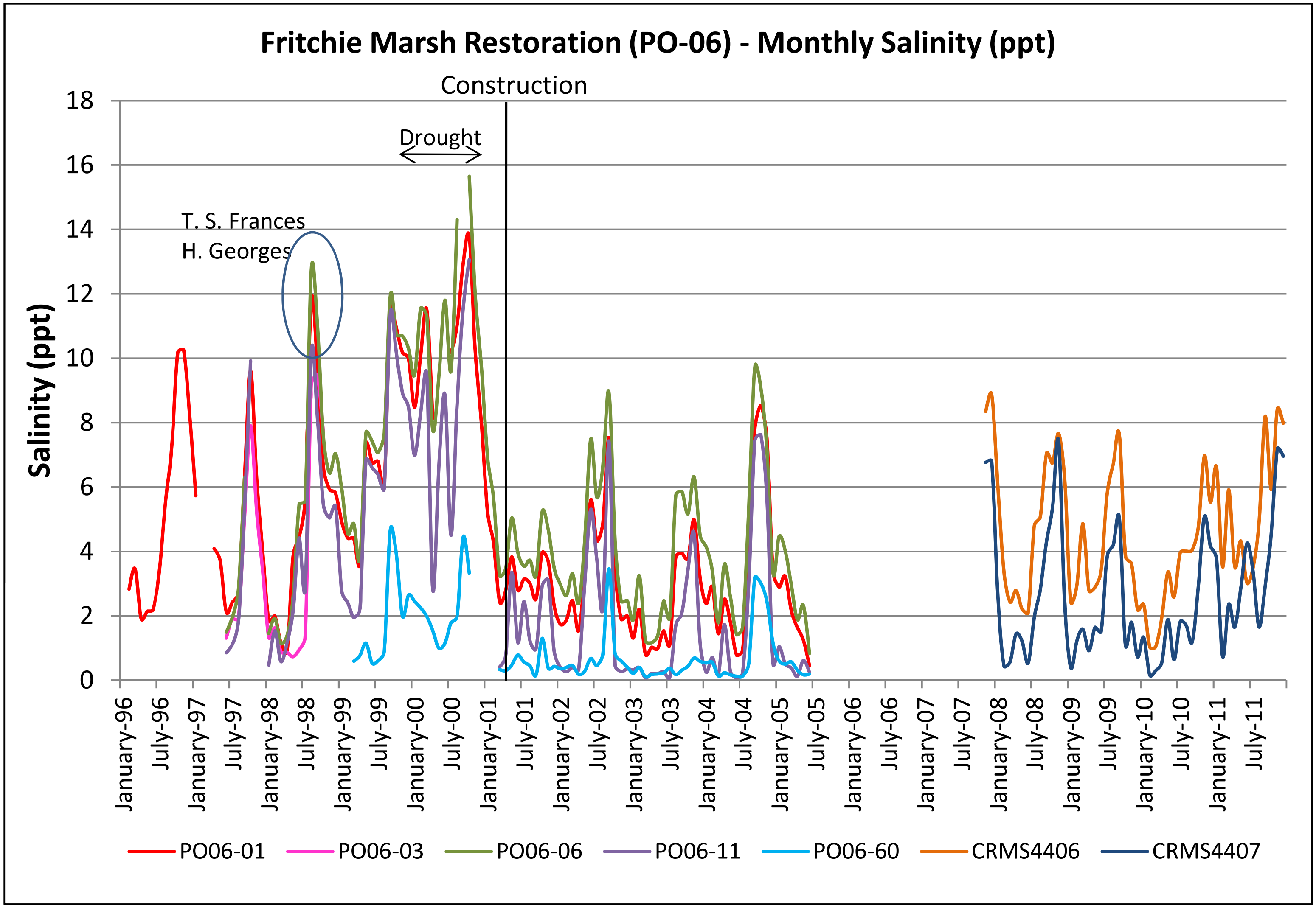

Figure 9. Monthly mean salinity for all continuous recorder stations within the Fritchie Marsh Restoration (PO-06) project area from 1996 to 2011.

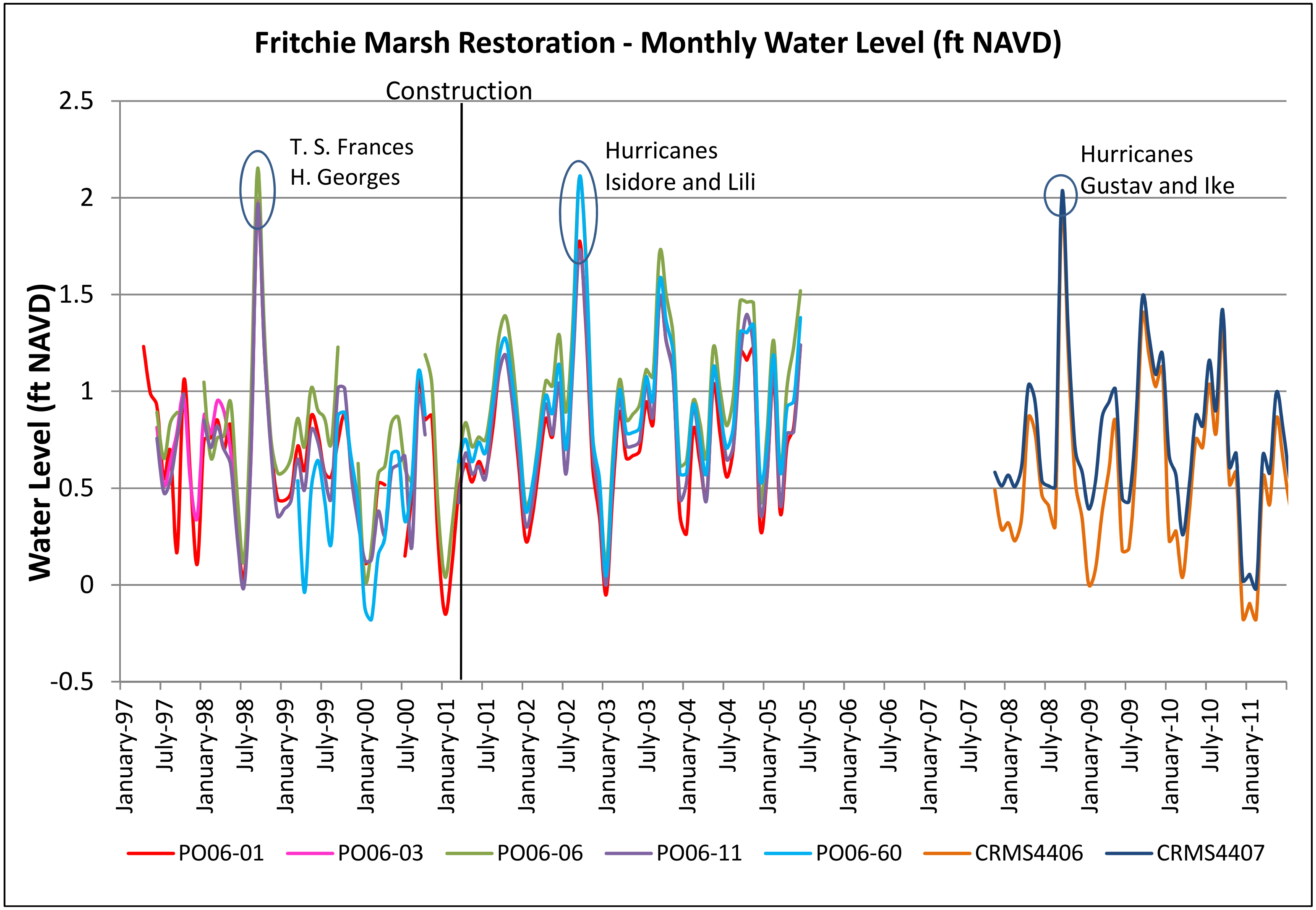

Figure 10. Monthly mean water level (ft NAVD88) for all continuous recorder stations within the Fritchie Marsh Restoration (PO-06) project area from 1996 to 2011.

Hydrologic conditions in the project area support this assumption. The design matches the one described in Table 1.b of Underwood (1994) with the difference that no sub-sampling takes place, so the residual error term is the *T(B)*L* interaction.

The statistical model depends on simultaneity of measurements among the various stations, treating each week in the study as a temporal block. For this reason, hourly salinity and water level measurements were aggregated into weekly means, with one week being sufficient to average out temporal lags among the stations during tidal and meteorological events. Another advantage to using weekly means (versus hourly means) is that they exhibit less serial correlation, i.e., greater sample independence, which is an important underlying assumption of the statistical model. Hourly salinity measurements were first transformed into common logarithms in order to better approximate the assumptions of normal distribution and uniform variance. These log salinities were then aggregated into weekly means on which the statistics are based.

The data show that the mean weekly salinity was lower and water level was higher at all four continuous recorder stations during the post-construction period (Figures 11 and 12). These data showed a significant interaction ($p<0.0001$) between stations in both the salinity and water level analyses. The significant *period* by *location* interaction indicates that the relative magnitude of changes in salinity and water level was different between stations indicating a project effect. These effects show up graphically as lines out of parallel in Figures 13 and 14. Interpretation of these results is complicated by the record-setting drought from September 1999 to December 2000, which led to increased salinity during some of the pre-construction period (Figure 9). The statistical design controls against this kind of nuisance fluctuation only under the assumption that the four sites would respond equally to the drought. In order to test this assumption, the analysis was repeated with the drought period removed. The *period* by *location* interaction was again found to be significant ($p<0.0001$) indicating that there was a significant project effect despite the occurrence of the drought.

Another complication is that the analysis may have created an interaction purely as an artifact of the low pre-construction salinity at Station 60, which is located near the 72-inch culvert (Figure 13). Testing the *period* by *location* interaction allows inference as to whether the post-construction drop in salinity at all of the stations may be attributed to project construction and not to a general downward fluctuation over the 10-year monitoring period. While the other stations all decreased in salinity by three to four parts per thousand, Station 60 began with a mean pre-construction salinity already at two parts per thousand and therefore lacked the range necessary to match this trend. Although the log transformation compensates for this, the analysis was repeated on the drought-deleted data with Station 60 removed to test whether the significant interaction was an artifact of the low salinity at Station 60. Again, the *period* by *location* interaction was significant ($p<0.0001$) indicating a project effect at the remaining stations. Station 11, which is located near the W-14 weir, experienced a greater drop in salinity (i.e., steeper slope) than stations 01 and 06. This indicates that the weir may be having a positive effect on the salinity in the area near Station 11. The decrease in salinity was very similar at

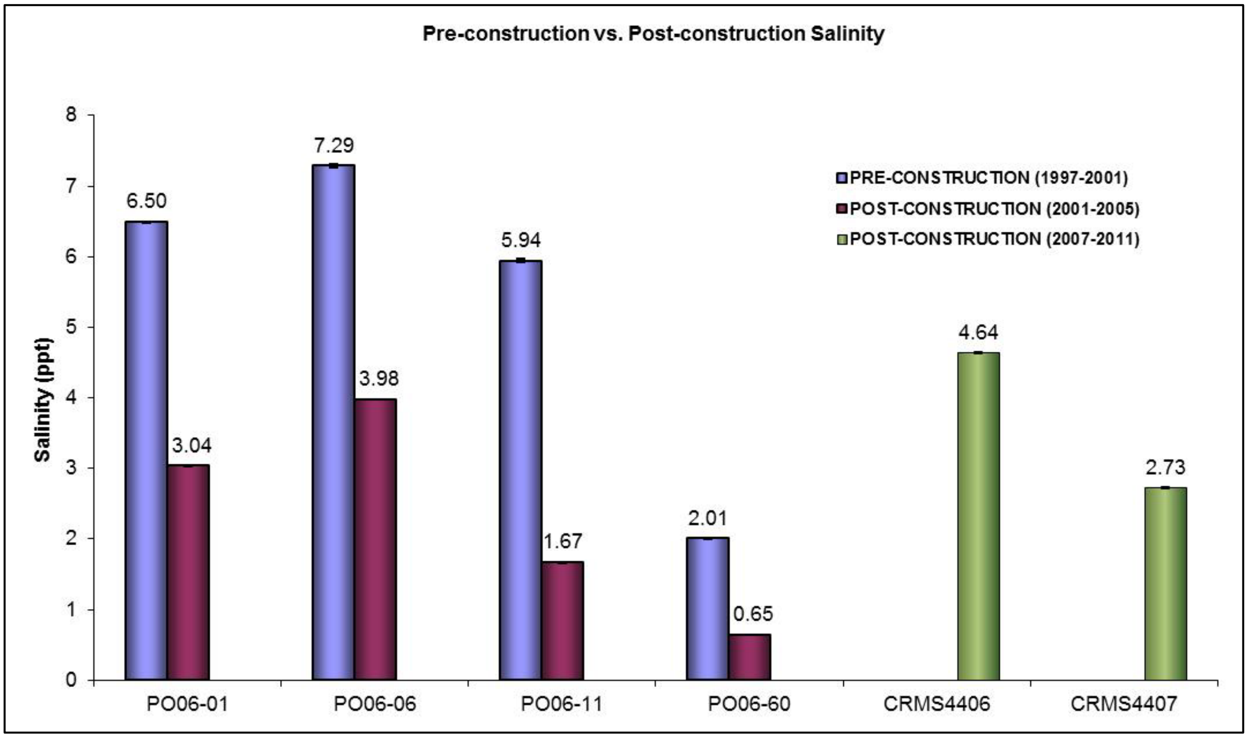

Figure 11. Mean weekly salinity at continuous recorder stations located in the Fritchie Marsh (PO-06) project area during pre-construction and post-construction periods.

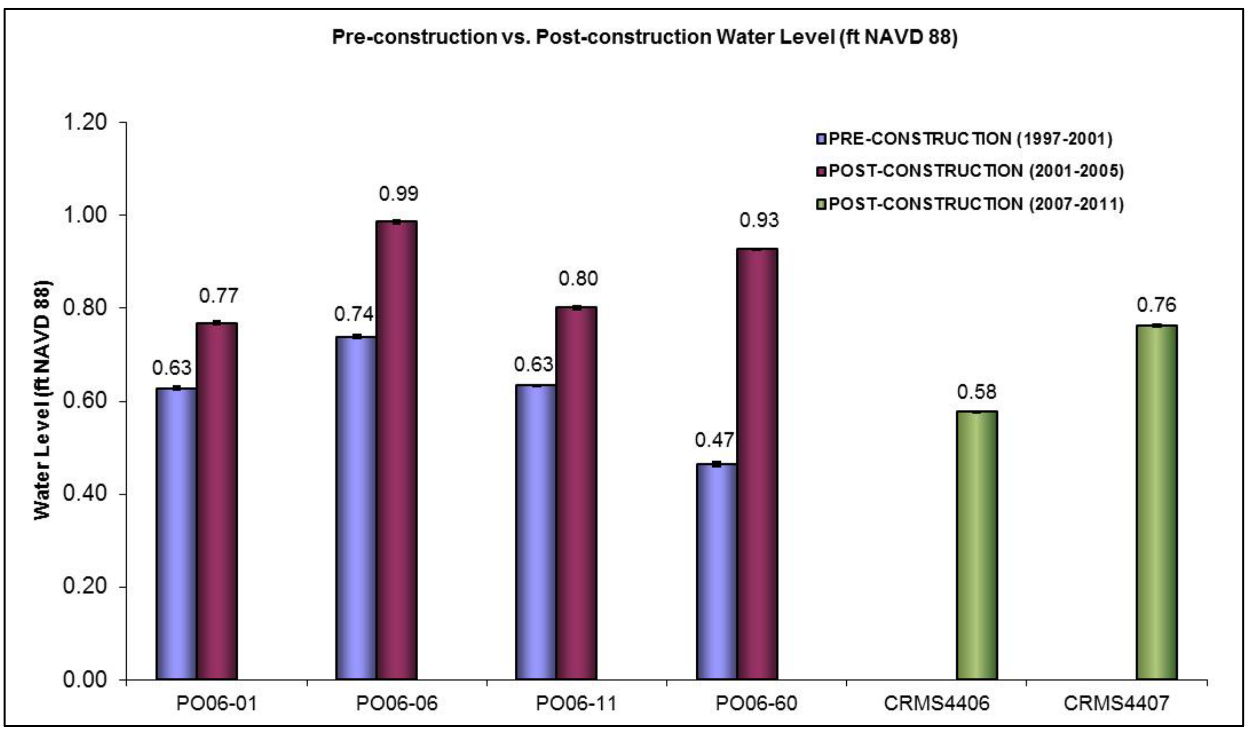

Figure 12. Mean weekly water level at continuous recorder stations located in the Fritchie Marsh (PO-06) project area during pre-construction and post-construction periods.

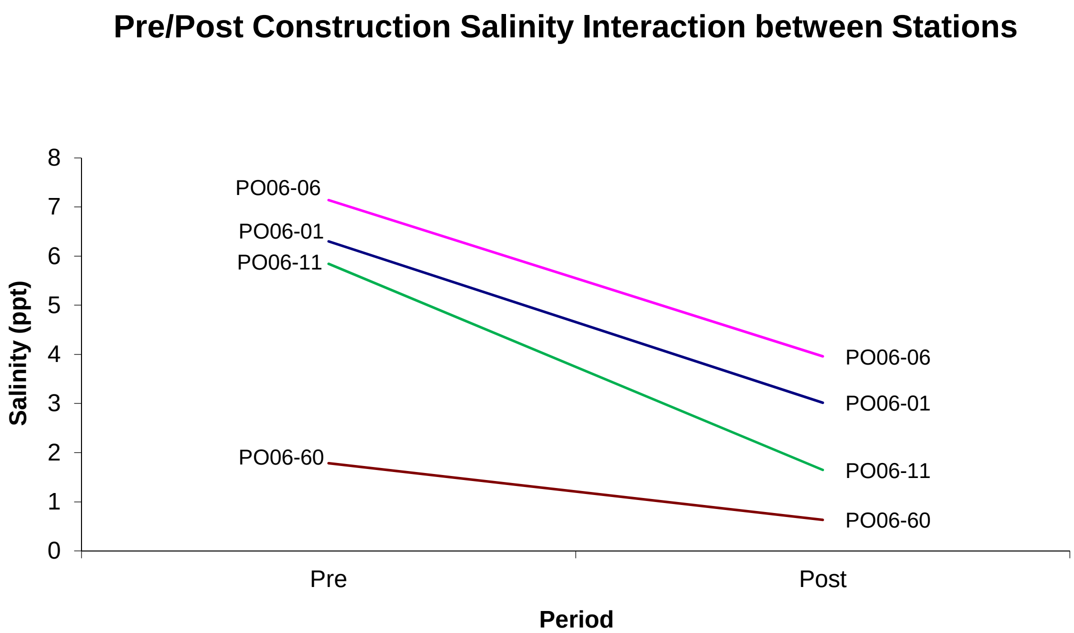

Figure 13. Interaction of mean weekly salinity during pre-construction and post-construction periods between four continuous recorder stations in the Fritchie Marsh Restoration (PO-06) project area. A significant interaction (*p<0.0001*) between stations was detected indicating a project effect.

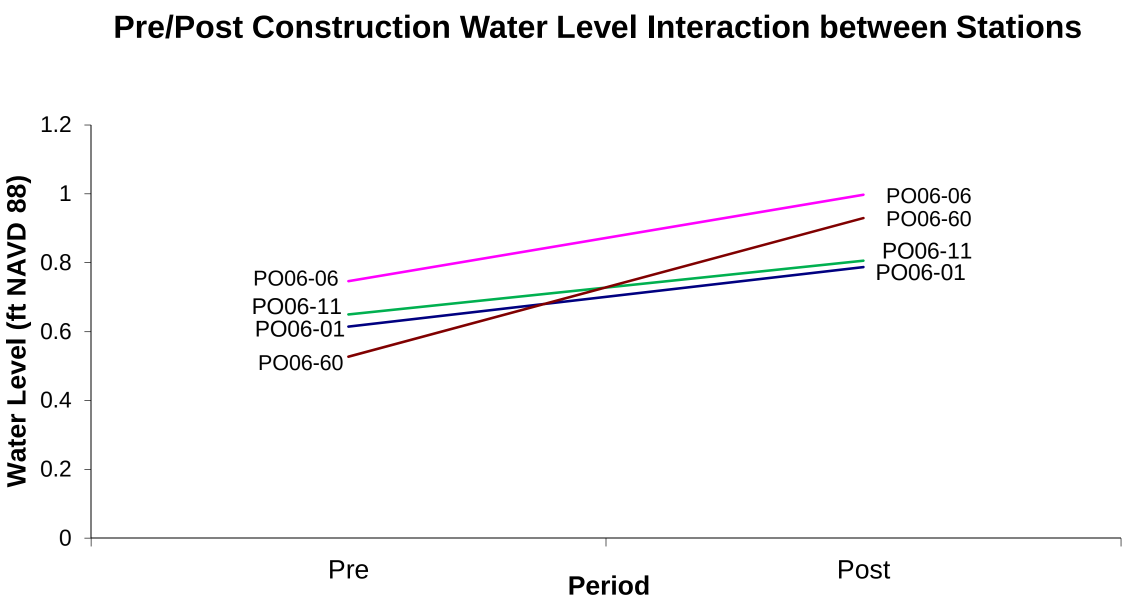

Figure 14. Interaction of mean weekly water level during pre-construction and post-construction periods between four continuous recorder stations in the Fritchie Marsh Restoration (PO-06) project area. A significant interaction (*p<0.0001*) between stations was detected indicating a project effect.

Stations 01 and 06, which indicates that the salinity at these stations is being affected by the project almost equally.

The interaction of mean water level between stations shows strong evidence of a project effect at Station 60 near the Hwy 90 culvert (Figure 14). Mean water level at this station was effectively doubled in the post-construction period. The magnitude of water level change was much greater at this station than at the other three stations, indicating that the addition of the culvert had a significant effect on water level. In contrast, the interaction results indicate that the W-14 weir has had comparatively less impact on water levels in the project area. Station 11, which is located near the weir, experienced an increase in water level very similar to that of Station 01. Station 06 experienced a slightly greater increase in water level than Stations 11 and 01. It should be noted, however, that the direct purpose of the weir was to reduce salinity in the marsh and not necessarily to increase water levels. Discrete water level readings recorded at 6 staff gauges on a monthly basis (at the 4 recorder stations and 2 additional stations) confirmed a post-construction increase in water level at all stations except PO06-03; however, the increase was not significant for any of the stations ($p>0.05$) (Figure 15). It should be noted that there were fewer readings from PO06-03 in both the pre-construction and post-construction periods due to difficulty accessing the station during low water periods.

Although salinity and water level monitoring ended at the PO-06 sites in 2005, hydrographic data collection has been ongoing at the two CRMS sites in the project area since November 2007. CRMS4406 is located mid-way along Salt Bayou in nearly the same location as former site PO06-01, while CRMS4407 is located in the northern project area nearest to former site PO06-11 (Figure 1). Mean weekly salinity at the CRMS sites from 2007 to 2011 was slightly higher than the post-construction salinity (2001 to 2005) at the PO-06 sites (PO06-01, PO06-11), but still lower than the pre-construction salinity (Figure 11). The increase in salinity in the post-construction period was lower in the northern project area (+1.1 ppt, CRMS4407 vs PO06-11) than at the Salt Bayou location (+1.6 ppt, CRMS4406 vs PO06-01). Mean weekly water level at CRMS4406 near Salt Bayou was 0.19 ft lower from 2007 to 2011 than was measured at PO06-01 from 2001 to 2005. In the northern project area, however, mean weekly water level was the same at CRMS4407 as post-construction levels at PO06-11 (0.04 ft difference) (Figure 12).

One explanation for lower water levels and slightly higher salinity at the Salt Bayou location from 2007 to 2011 is heavy siltation along Salt Bayou, which restricts fresh water flow from the Hwy 90 culvert. During an inspection of the project features in March 2006, it was noted that a considerable amount of Salt Bayou was inaccessible due to large amounts of sediment that had been deposited into the bayou by Hurricane Katrina, greatly reducing the movement of water. The portion of Salt Bayou primarily affected is located between the hydrographic monitoring location (PO06-01/CRMS4406) and the Hwy 90 culvert. Freshwater influence from the culvert is now reduced at this site, while brackish water continues to enter the system from Lake Pontchartrain at the other end of Salt Bayou. In fact, the salinity at CRMS4406 appears more similar to the post-construction salinity at PO06-06, which was located closer to the lake (Figure 1, Figure 11). Subsequent project inspections have determined that breaches along the banks of Salt Bayou near the culvert are still allowing fresh water to enter the project area (see Section II, b), and therefore the project is still functioning as designed. In the northern project area, water level and salinity data show relatively small changes before and after Hurricane Katrina, and therefore Salt Bayou siltation does not seem to be affecting this portion of the project. In fact, the salinity increase of ~1 ppt in the post-Katrina period may be due to the location of CRMS4407 which is located further from the W-14 Canal than PO06-11. Even the salinity increase of 1.6 ppt at the Salt Bayou location is relatively small and may have little ecological impact considering the wide salinity range of an intermediate to brackish marsh. There are no plans to re-dredge Salt Bayou at this time, but water level and salinity data will continue to be monitored at the CRMS sites to determine if any action will be needed in the future.

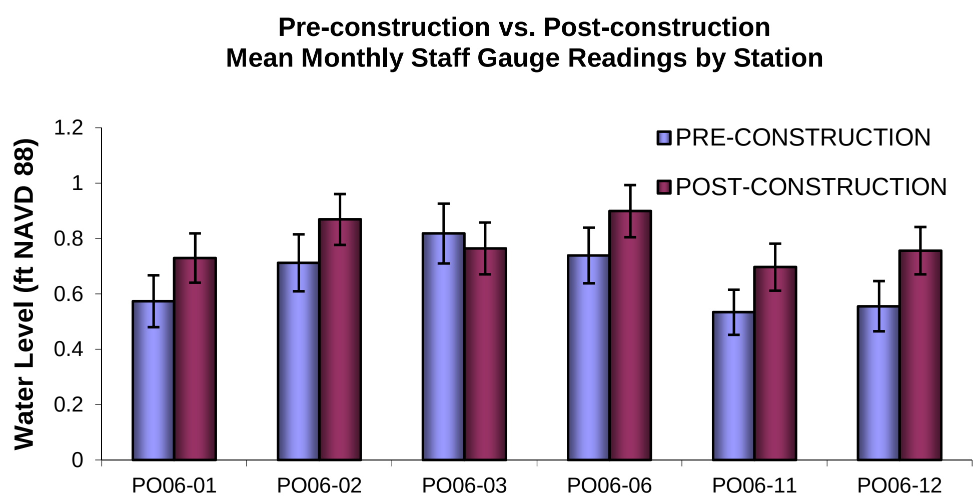

Figure 15. Mean of monthly staff gauge readings at the six staff gauges located in the Fritchie Marsh (PO-06) project area during the pre-construction (3/98-2/01) and post-construction (3/01-6/05) periods.

Vegetation

Pre-construction vegetation surveys were conducted in late summer/early fall of 1997 and 2000, and post-construction surveys were conducted in 2004, 2007, and 2010 at 29 sample plots within the project area (Figure 16). The project area was dominated by *Spartina patens* (saltmeadow cordgrass) in all survey years in terms of both frequency of occurrence and mean percent coverage (Figure 17, Table 2). *S. patens* was found within 97-100% of the plots in each of the survey years. Total number of species was similar between sample years and ranged from 28 to 34, except in year 2000 in which 21 species were observed. This is most likely due to the severe drought that preceded the 2000 survey, which inhibited the growth of some fresh/intermediate species. Total percent cover of vegetation was greatest in 1997, the first year sampled, and was lowest in 2000 following the drought (Figure 17). Total percent cover remained relatively stable during the post-construction period from 2004 to 2010 with a slight dip in 2007 following Hurricane Katrina. However, it should be noted that nine of the original 29 stations converted to open water in the post-Katrina sample years (2007 and 2010) and were re-established within the nearest land mass. When total percent cover is calculated using the original 29 stations, then 2007 and 2010 have the lowest total percent cover of all the sampling years (Figure 18).

Vegetation was also surveyed annually at the two CRMS sites within the project area, CRMS4406 and CRMS4407, from 2007 to 2011. Ten 2 x 2-m plots were sampled within a 200-m^2 area at each CRMS site. Species composition and abundance at CRMS4406, which is located mid-way along Salt Bayou, was similar to the PO-06 sites (Figure 19). *S. patens* was the dominant species, with other species including *Schoenoplectus americanus* (Olney's threesquare) and *Distichlis spicata* (saltgrass). Total percent cover at CRMS4406 dropped to below 60% in 2008, but has shown a steady increase in subsequent years. At CRMS4407, which is located in the northwestern portion of the project area, the vegetation transect runs partially through a dense stand of *Phragmites australis* (common reed) (Figure 20). Percent cover of *P. australis* at CRMS4407 has remained steady since 2007 at about 40%. Plots which fall within the *P. australis* are highly mono-specific with very few other species occurring. However, species composition and abundance within the remaining plots are highly variable and are more characteristic of fresh to intermediate marsh.

One tool that has been used to assess the quality of the vegetation community at the CRMS sites is the Floristic Quality Index (FQI) (Cretini et al. 2011). The FQI is calculated by assigning each species a CC score, or coefficient of conservatism, which is scaled from 1 to 10 and reflects a species' tolerance to disturbance and habitat specificity. A modified FQI was developed by the CRMS Vegetation Analytical Team, which assembled a team of experts to assign CC scores to Louisiana's wetland plant species. The modified FQI equation takes into account not only the CC scores, but also the percent covers of species at a site, and the resulting score is scaled from 0 to 100. Mean FQI scores were calculated for the PO-06 project sites and CRMS sites for each of the sampling years (Figures 17, 19, and 20). FQI scores for the PO-06 sample years were

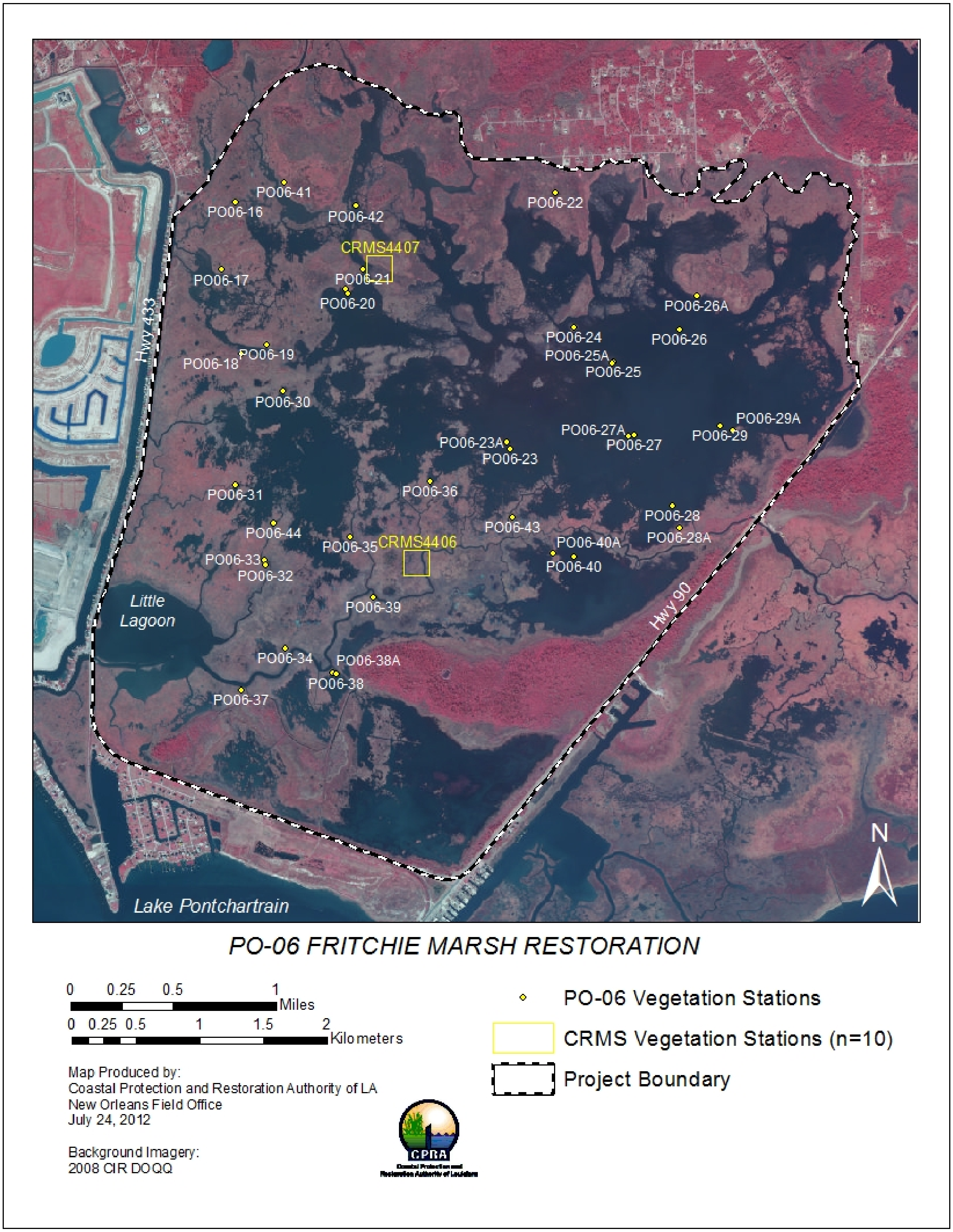

Figure 16. Vegetation stations located within the Fritchie Marsh Restoration (PO-06) project.

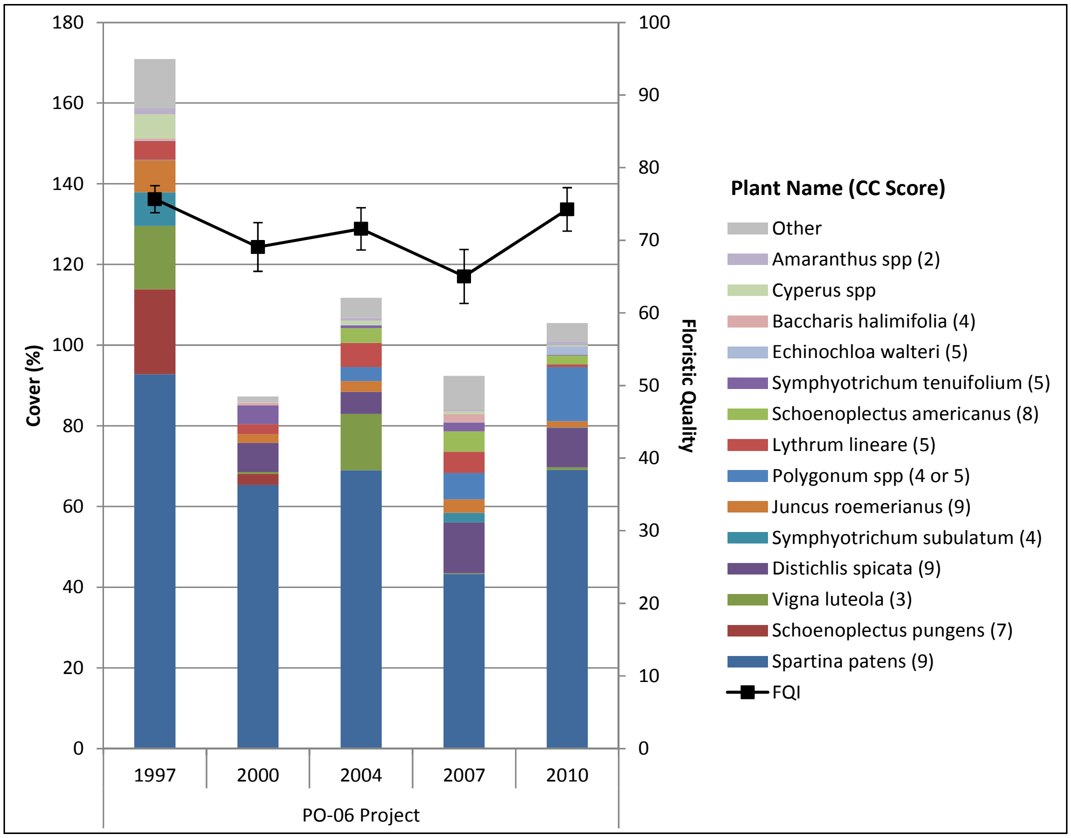

Figure 17. Mean percent cover of species within the PO-06 project area and the Floristic Quality Index (FQI) score for each sample year. The CC score represents the quality of the individual species on a scale from 1 to 10 where 1 represents disturbance species and 10 indicates species found in stabile environments.

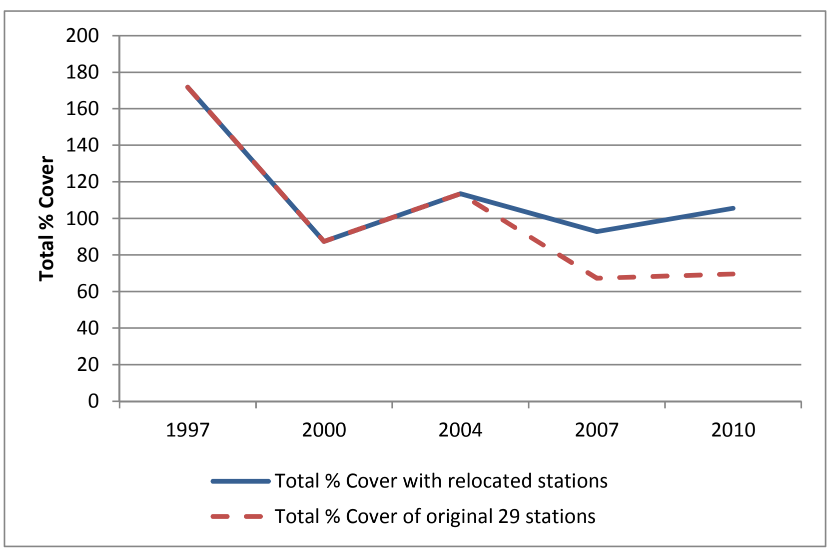

Figure 18. Total mean % cover of vegetation within the PO-06 project area (n=29 stations) when calculated with relocated stations (n=9) vs. all original stations.

Table 2. The percentage of the total number of vegetation plots where each species occurred and the mean percent cover of species within plots where they occurred during the 1997, 2000, 2004, 2007, and 2010 vegetation sampling of the PO-06 project area.

Scientific Name	Occurrence of Total Plots (%)					Mean % Cover in Plots where Species Occurred				
	1997	2000	2004	2007	2010	1997	2000	2004	2007	2010
Spartina patens	100	100	100	97	97	93	65	69	45	72
Lythrum lineare	44	31	59	76	24	10	8	10	7	3
Distichlis spicata	*	48	34	41	34		15	16	31	28
Vigna luteola	52	17	45	17	24	30	3	31	1	3
Polygonum spp	4		34	24	59	4		10	27	23
Symphyotrichum tenuifolium		45	17	24	14		11	4	9	1
Schoenoplectus americanus			28	41	28			13	12	8
Juncus roemerianus	24	21	14	14	21	33	10	19	24	7
Amaranthus spp	20	17	14	17	24	7	1	5	3	4
Ipomoea sagittata	24	24	10	10	17	12	1	2	4	16
Cyperus odoratus	40		17	10	17	7		4	3	1
Schoenoplectus pungens	44	21				48	13			
Echinochloa walteri	8		21	7	24	3		1	2	9
Iva frutescens	4	10	*	31	14	20	5		14	2
Cyperus spp	20	3	10	7	17	16	5	2	7	1
Ammannia spp	16		24	10	7	8		3	0	1
Symphyotrichum subulatum	36			10	3	23			23	3
Pluchea spp	12	7	14	3	10	11	3	11	12	1
Bacopa monnieri	4	21		7	3	5	1		1	10
Baccharis halimifolia	4	14		10	*	10	4		19	
Eleocharis cellulosa	8		10	3	3	45		18	2	2
Eleocharis spp	4	3	17			5	3	12		
Galium tinctorium			21					1		
Schoenoplectus robustus	*			3	14				3	2
Panicum repens	8				3	9				5
Kosteletzkya virginica	8	*	*	*		1				
Eclipta prostrata	8					1				
Ludwigia leptocarpa	4		3			1		3		
Sagittaria lancifolia	4		3		*	25		1		
Paspalum vaginatum				3	3				85	2
Hydrocotyle spp	*		7					1		
Cuscuta spp					7					1
Leptochloa fusca				*	7					1
Phragmites australis	4	*				25				
Alternanthera philoxeroides		*	3		*			1		
Boehmeria cylindrica			3					1		
Sabatia spp			*		3					3
Sesbania herbacea	*				3					5
Echinochloa crus-galli					3					1
Setaria parviflora				3					2	
Spartina cynosuroides				3					10	
Fimbristylis castanea			*							
Pennisetum glaucum			*							
Setaria pumila	*	*		*	*					
Solidago sempervirens	*	*								
Andropogon glomeratus	*									
Panicum dichotomiflorum	*									
Setaria magna	*									
Spartina alterniflora		*								
Sacciolepis striata				*						
Typha spp				*						
Total # of species	34	21	28	29	31					

***Species were found within 15-ft outside of the vegetation plots.**

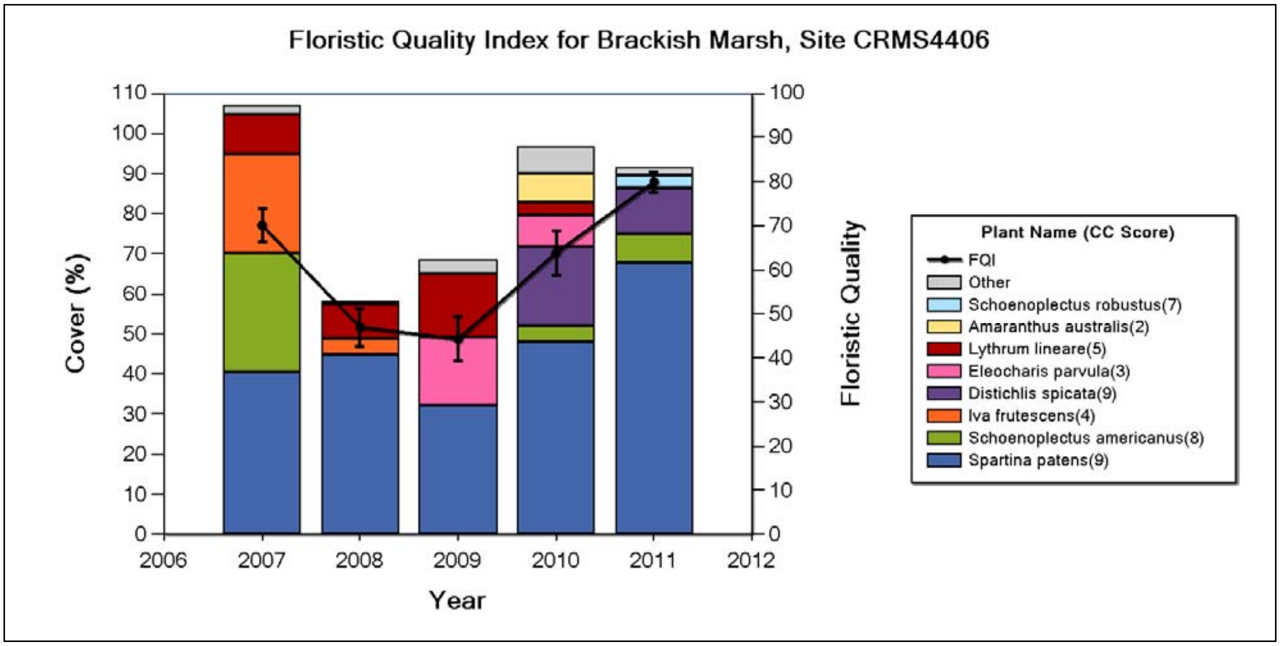

Figure 19. Mean % cover of major species and FQI score at CRMS4406 from 2007 to 2011.

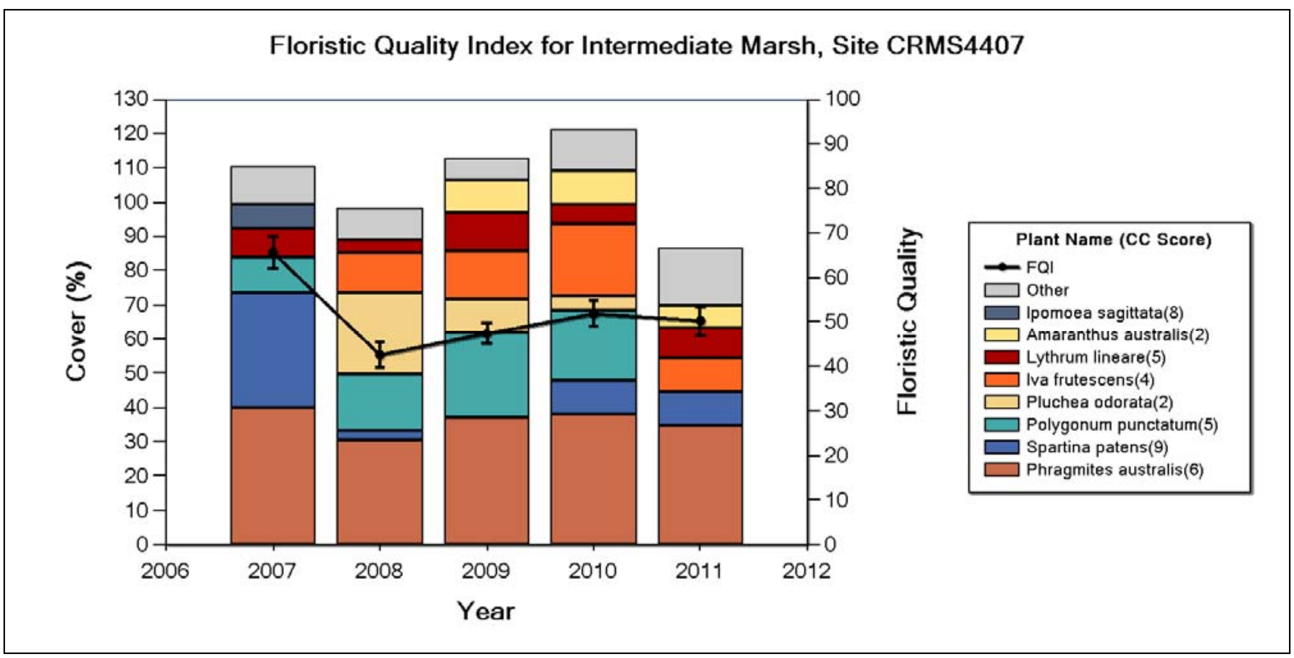

Figure 20. Mean % cover of major species and FQI score at CRMS4407 from 2007 to 2011.

relatively stable and generally mirrored fluctuations in percent cover of *S. patens*, which is assigned a high CC score of 9. FQI scores ranged from 65 to 76, which is just below the ideal range of 80-100 for intermediate/brackish marsh, as estimated by the CRMS Vegetation Analytical Team (Cretini et al. 2011). The FQI score at CRMS4406 dropped below 50 in 2008 and 2009, perhaps due to Hurricanes Gustav and Ike, but has since rebounded to about 80 in 2011. FQI score at CRMS4407 has been stable at about 50 since 2008. The lower FQI scores at this site are attributable to the higher abundance of fresh/intermediate species, which are often associated with disturbance and therefore have lower CC scores.

The main goal of the Fritchie Marsh Restoration project was to increase the flow of fresh water into the project area. A decrease in salinity within the project area may be reflected within the vegetation community through a transition from brackish to a more fresh/intermediate community type. In order to detect transitions in marsh type within the project area, marsh types were automatically generated by species composition and cover data for all individual sample plots. Marsh types were calculated through an algorithm described in Visser et al. 2002, in which each species present is assigned a salinity score based on the marsh type in which it is most commonly found. As expected, generated marsh types were mostly intermediate to brackish (Figures 21 and 22). Only one plot was characterized as fresh and the occasional plot assigned as saline was generally due to the presence of *D. spicata* (saltgrass). The percentage of plots for each sample year that were charactized as fresh/intermediate was calculated to determine trends in this community type over time. The PO-06 plots and CRMS plots both showed a general downward trend in percentage of fresh/intermediate plots over time (Figures 23 and 24). The trend is weaker for the PO-06 sample years (r^2=0.165) and is mainly attributable to the comparatively high number of intermediate plots observed in 1997. The % of plots classified as intermediate dropped from 92% in 1997 to 45% in the drought year of 2000, so this trend began before project construction (Figure 23). In the post-construction period, which included the effects of Hurricane Katrina, the number of fresh/intermediate plots has ranged from 48 to 66% and appears relatively stable. The two CRMS sites, however, displayed a strong trend (r^2=0.9135) toward a more brackish community from 2007 to 2011 (Figure 24). It should be noted that the CRMS plots are not distributed as evenly throughout the project area as the PO-06 sites and may be subject to localized differences in vegetation, such as the presence of *P. australis* at CRMS4407. In general, it does not appear that the project features are inducing a shift toward a fresher community structure at the PO-06 or CRMS sites at this time. Transition in marsh type is not a direct indicator of project success, but can merely demonstrate whether increased freshwater input is inducing changes within the community structure. Many additional stressors also impact the vegetation community, such as drought and hurricanes, which can counteract project effects. It is possible that the project features may have dampened the impacts of stressors such as drought and hurricanes, which may have caused an even greater shift toward a brackish/saline community.

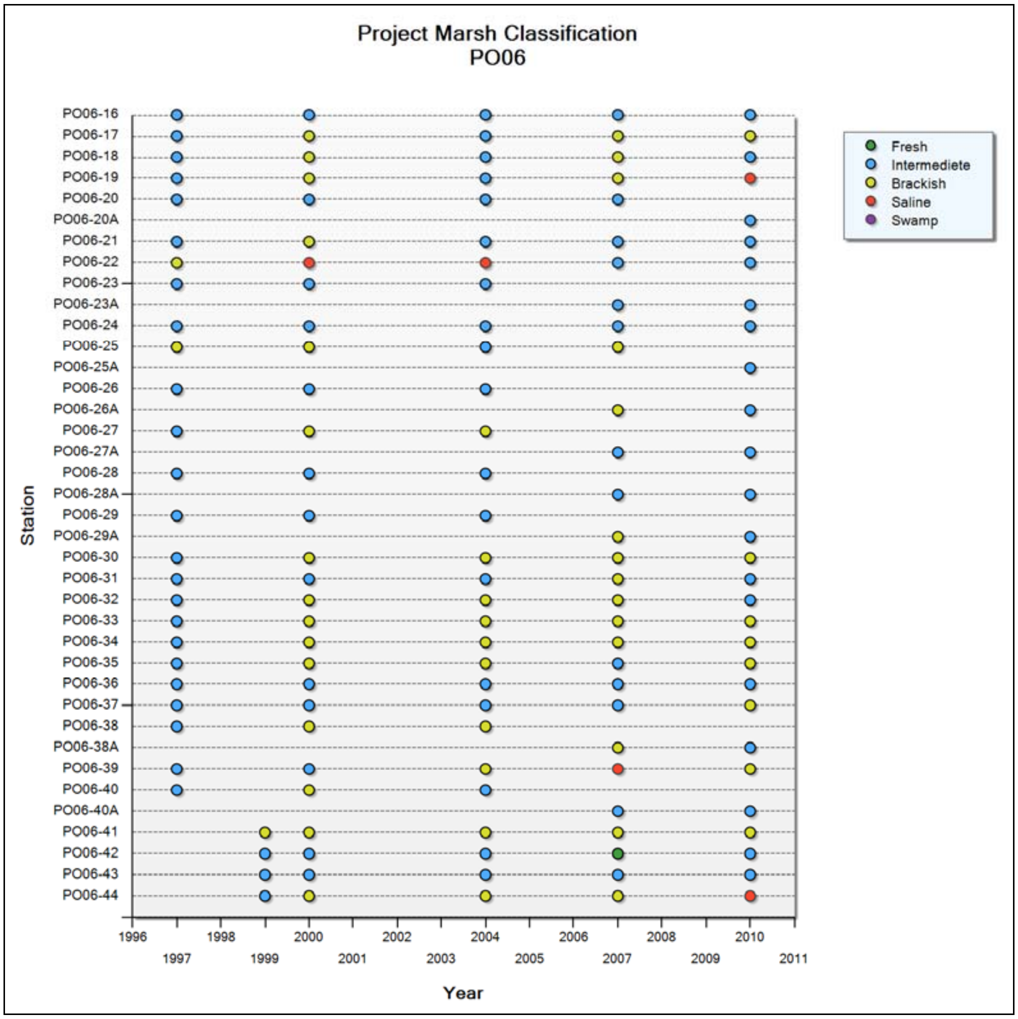

Figure 21. Marsh classification of PO-06 vegetation stations from 1997 to 2010.

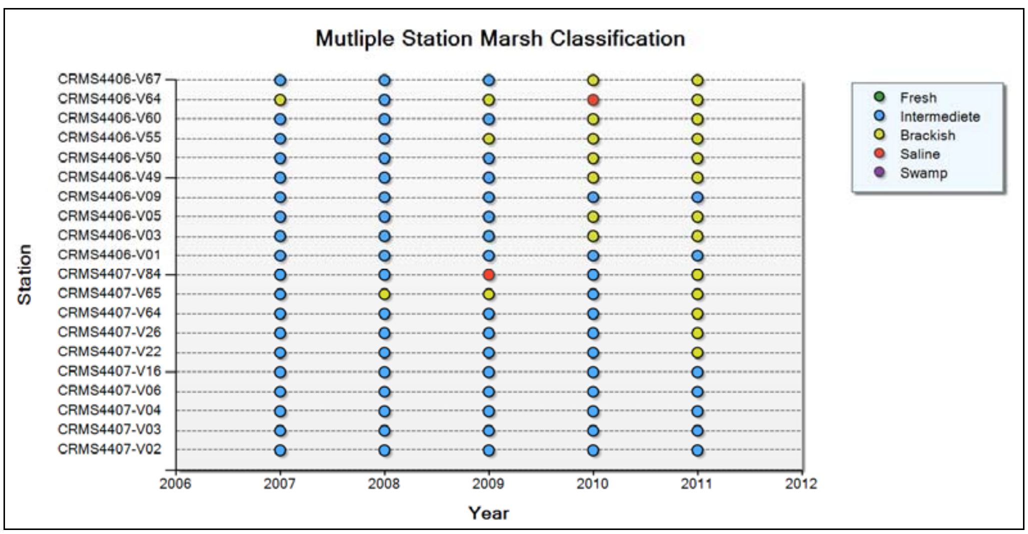

Figure 22. Marsh classification of CRMS4406 and CRMS4407 vegetation stations from 2007 to 2011.

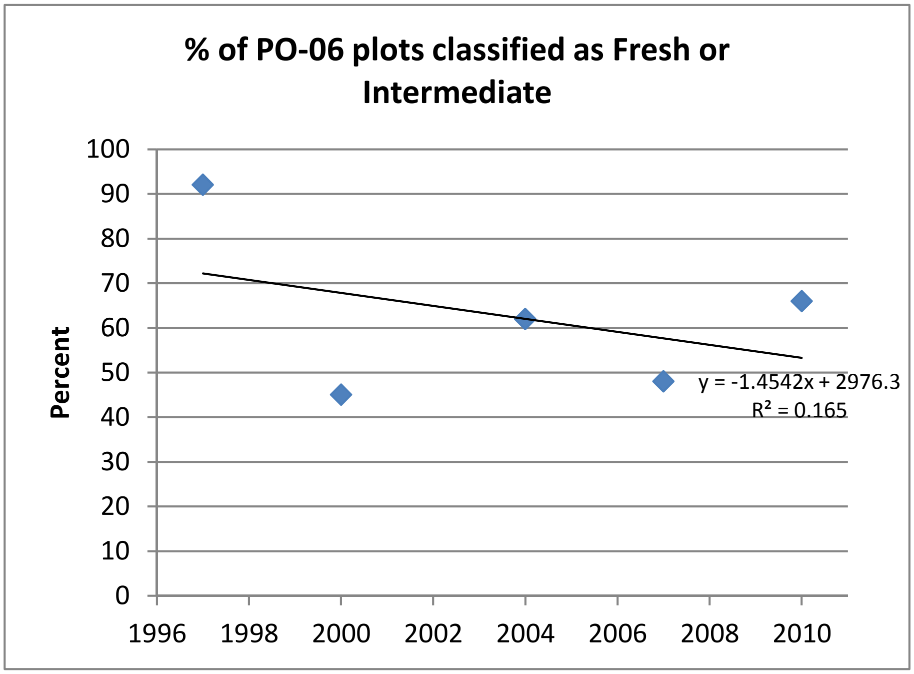

Figure 23. Percentage of PO-06 vegetation plots classified as fresh/intermediate from 1997 to 2010.

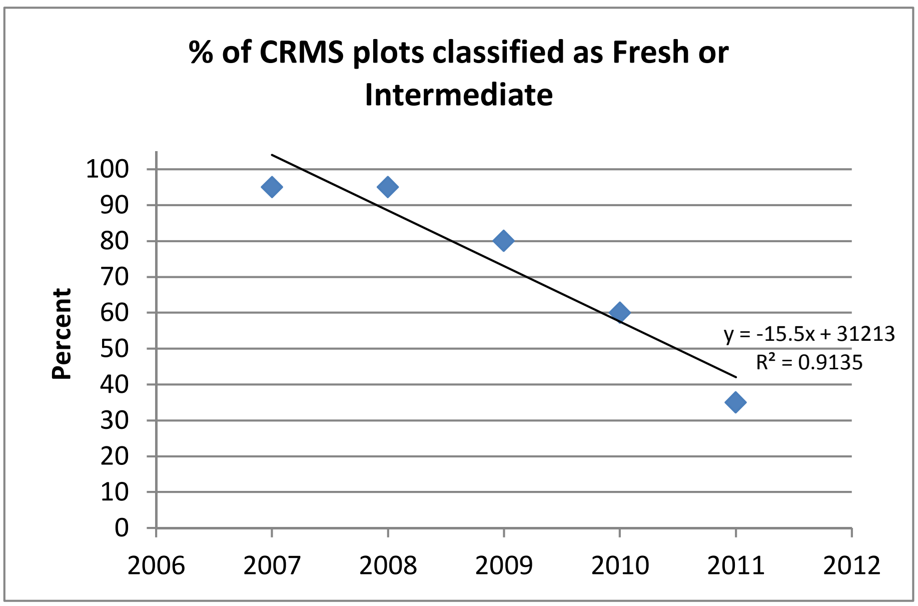

Figure 24. Percentage of CRMS vegetation plots within the Fritchie Marsh Restoration (PO-06) project area classified as fresh/intermediate from 2007 to 2011.

CRMS Supplemental

Three soil cores were extracted from each CRMS site on June 17, 2008 and were analyzed for bulk density and % organic content in 4-cm increments down to 24 cm. Low mean bulk densities below 0.2 g cm^{-3} were observed at both sites (Figure 25), while % organic matter was slightly higher at CRMS4407 than at CRMS4406 (Figures 26). Marsh elevation change and vertical accretion data are also being collected at CRMS4406 and CRMS4407, but the current estimates are preliminary and will not be presented until sufficient data has been collected.

V. Conclusions

a. Project Effectiveness

The constructed features of the Fritchie Marsh Restoration Project appeared to be having the desired effect on the hydrology of Fritchie Marsh through the end of the project-specific monitoring period in June 2005. Mean salinity was lower and mean water level was higher during the post-construction period, suggesting increased flow of freshwater into the project area. Although this response would be expected during the post-construction period due to post-drought conditions, a project effect was detected for both salinity and water level even with the drought period removed. In August 2005, however, the center of Hurricane Katrina passed just to the east of the Fritchie Marsh Project area causing significant damage to the marsh and altering the natural hydrology of the area. Large areas of marsh were converted to open water, and fragments of sheared marsh were deposited into the natural bayous and canals creating a number of blockages. Existing breaches on the banks of Salt Bayou were enlarged and new breaches were created, which are now diverting water away from the natural conveyance channels. CRMS data from the post-Hurricane Katrina period show lower water levels and slightly higher salinity mid-way along Salt Bayou, which may be attributed to Salt Bayou siltation. Fresh water from the Hwy 90 culvert, however, still appears to be entering the main project area through several breaches along Salt Bayou nearer to the culvert; therefore, the goal of bringing fresh water into the project area is still being achieved. Post-construction salinity and water levels in the northern project area were similar before and after Hurricane Katrina, so the altered hydrology does not appear to be having an effect throughout the entire project area.

The land loss rate within the project area before Hurricane Katrina dropped from -31.5 ac/yr before construction to +3.3 ac/yr after construction, indicating that the project features may have been having a positive effect on land loss rates before the storm. Hurricane Katrina, however, caused a significant land loss of 916 acres or 14.6% of the total project acreage. Fortunately, land/water analyses of the CRMS sites in the post-Katrina period indicated that land acreage stabilized after the storm. The vegetation community within the project area appears to be relatively stable based on the Floristic Quality Index values. The marsh type can be classified as intermediate to brackish and

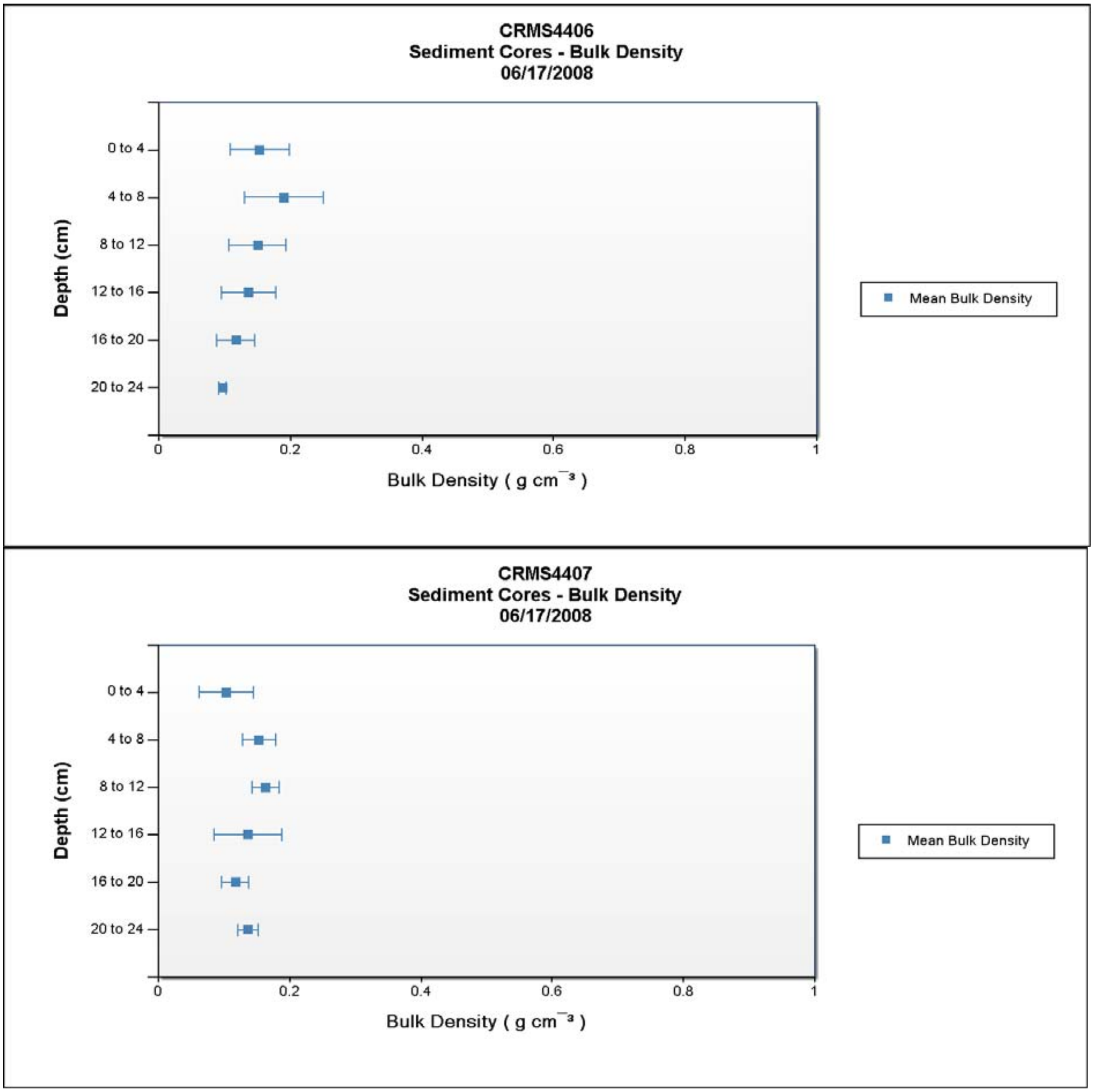

Figure 25. Bulk density (g cm^{-3}) of the CRMS baseline soil samples collected in June 2008 within the Fritchie Marsh Restoration (PO-06) project.

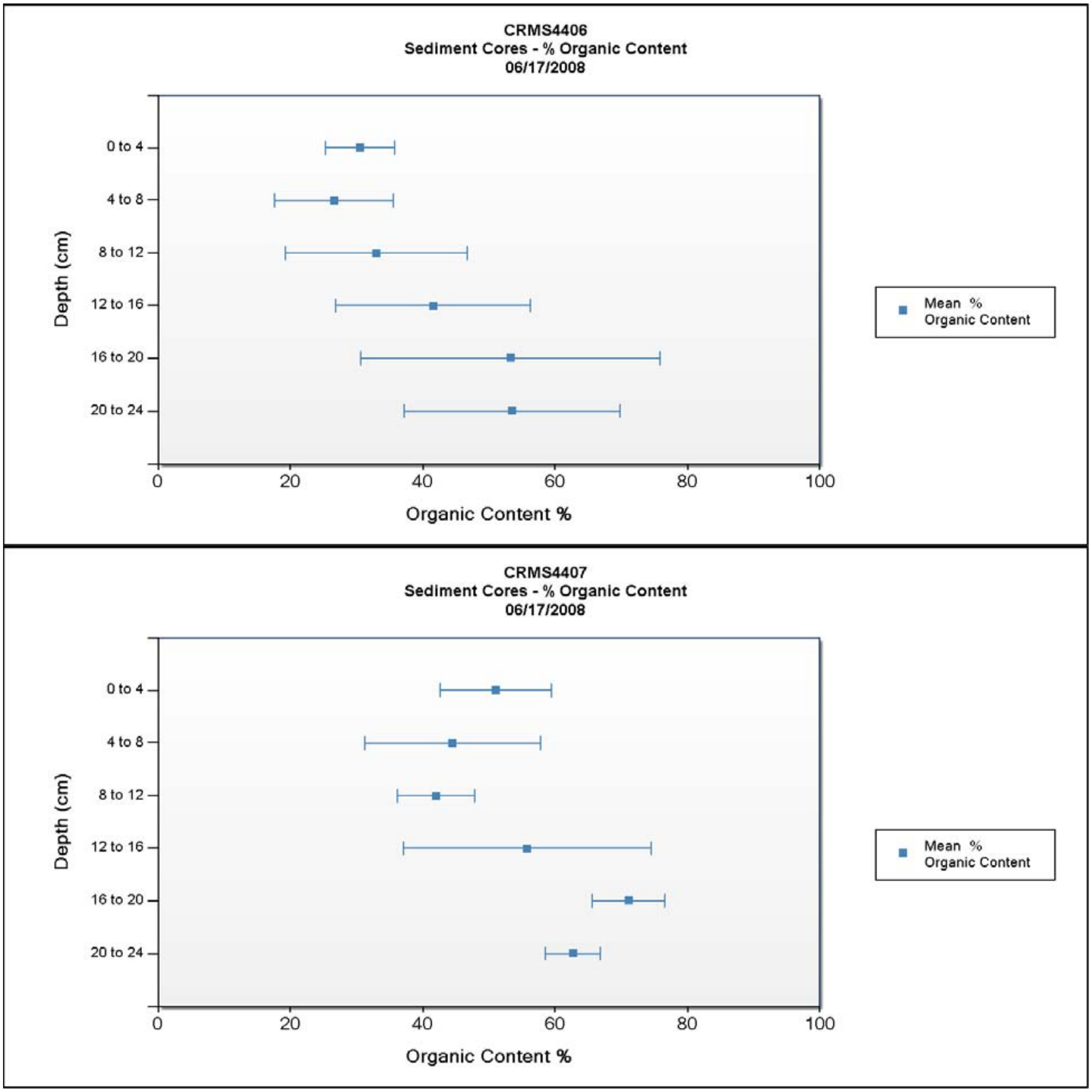

Figure 26. Mean organic content (%) of the CRMS baseline soil samples collected in June 2008 within the Fritchie Marsh Restoration (PO-06) project.

continues to be dominated by *Spartina patens*. Data indicated a trend toward a more brackish marsh type over the entire sampling period from 1997 to 2010. However, the trend was much stronger in the post-Katrina period at the CRMS sites. Drought and storms effects may be having a greater influence on the vegetation community structure than the project features.

b. Recommended Improvements

CPRA and NRCS agree that there is no need to re-dredge Salt Bayou, as indicated in the previous OM&M report. Fresh water from the Hwy 90 culvert enters the project area through several breaches along the bank of Salt Bayou. Fresh water is still able to flow down the length of Salt Bayou, although the flow is now reduced.

c. Lessons Learned

Monitoring activities are inherently linked to project feature construction. Construction delays can often result in the need to repeat pre-construction monitoring data collection due to changes in site conditions when construction is delayed. Because of construction delays of the Fritchie Marsh Restoration Project, an extra round of pre-construction habitat analysis and vegetation monitoring was conducted in the year 2000, which was an unanticipated cost.

Climatic anomalies, such as drought, may confound hydrologic data results, especially in cases where a reference area was not monitored. In this case, however, a suitable reference area for hydrologic monitoring did not exist. The Coastwide Reference Monitoring System (CRMS) now provides valuable pre/post-construction reference data for more recently constructed projects.

Extreme weather events, such as Hurricane Katrina, create additional challenges in the maintenance and monitoring of coastal restoration projects. In this case, the storm altered the hydrology of the project area and caused significant marsh loss. In the wake of such events, adaptive decision-making is important when determining whether original project features should be maintained (i.e, Salt Bayou dredging). Additionally, the effects of project features can be difficult to distinguish amid extreme storm impacts such as Hurricane Katrina.

The most important lesson we should learn in the selection and design of future hydrologic restoration projects is to properly consider the structural integrity of existing topographic features, i.e., spoil banks, cheniers, etc., that our project structures will depend on to function. In the event they can be compromised through subsidence, increased water velocity, or erosion during the 20-year life of the project, then proper consideration should be given to the maintenance efforts and costs and these costs should be included in the selection criteria.

VI. References

CPRA (formerly LDNR) 2002. Operation, Maintenance, and Rehabilitation Plan for the Fritchie Marsh Restoration Project (PO-06). Coastal Protection and Restoration Authority of LA (formerly LDNR), New Orleans, LA. July 10, 2002.

Cretini, K. F., J. M. Visser, K. W. Krauss, and G. D. Steyer 2011. CRMS Vegetation Analytical Team framework—Methods for collection, development, and use of vegetation response variables. U.S. Geological Survey Open-File Report 2011-1097, 60 pp.

Folse, T. M., J. L. West, M. K. Hymel, J. P. Troutman, L. A. Sharp, D. K. Weifenbach, T. E. McGinnis, L. B. Rodrigue, W. M. Boshart, D. C. Richardi, C. M. Miller, and W. B. Wood. 2008, revised 2012. A Standard Operating Procedures Manual for the Coast-wide Reference Monitoring System-*Wetlands*: Methods for Site Establishment, Data Collection, and Quality Assurance/Quality Control. Louisiana Coastal Protection and Restoration Authority. Baton Rouge, LA. 207 pp.

Mueller-Dombois, D. and H. Ellenberg 1974. *Aims and Methods of Vegetation Ecology*. New York: John Wiley and Sons. 547 pp.

Smith, Eric P. 2002. BACI Design. *Encyclopedia of Environmetrics, Volume 1*. pp. 141-148. A. H. El-Shaarawi and W. W. Piegorsch, *Eds*. John Wiley & Sons, Ltd., Chichester.

Stewart-Oaten, A., W. W. Murdoch, and K. R. Parker 1986. Environmental impact assessment: Pseudoreplication in time?. *Ecology*, 67. pp. 929-940.

Steyer, G. D., R. C. Raynie, D. L. Steller, D. Fuller, and E. Swenson 1995, revised 2000. *Quality Management Plan for Coastal Wetlands Planning, Protection, and Restoration Act Monitoring Program*. Open-file report no. 95-01. Louisiana Department of Natural Resources, Coastal Restoration Division, Baton Rouge, LA. 97 pp. plus appendices.

Underwood, A. J. 1994. On beyond BACI: Sampling designs that might reliably detect environmental disturbances. *Ecological Applications*, 4 (1). pp 3-15.

Visser, J.M., Sasser, C.E., Chabreck, R.H., Linscombe, R.G. 2002. The impact of a severe drought on the vegetation of a subtropical estuary. Estuaries 25: 1184-1195.

Appendix A
(Inspection Photographs)

Photo #1. Salt Bayou Bank Scour Near Culverts

Photo #2. Culverts from Project Side of Hwy 90

Photo #3. W-14 Weir

Photo #4. W-14 Diversion Channel Beyond Dredging

Appendix B
(Three Year Budget Projection)

Fritchie Marsh Hydrologic Restoration (PO-06)
Federal Sponsor: NRCS
Construction Completed : March 6, 2001
PPL 2

Current Approved O&M Budget June 2009	Year 0 FY02	Year - 1 FY03	Year -2 FY04	Year -3 FY05	Year -4 FY06	Year -5 FY07	Year -6 FY08	Year -7 FY09	Year -8 FY10	Year -9 FY11	Year -10 FY12	Year -11 FY13	Year -12 FY14	Year -13 FY15	Year -14 FY16	Year -15 FY17	Year -16 FY18	Year - 17 FY19	Year -18 FY20	Year -19 FY21	Project Life Budget	Currently Funded
State O&M																					$225,211	$225,211
Corps Admin																					$0	$0
Federal S&A																					$0	$0
Total																					$225,211	$225,211

Projected O&M Expenditures	Year 0 FY02	Year - 1 FY03	Year -2 FY04	Year -3 FY05	Year -4 FY06	Year -5 FY07	Year -6 FY08	Year -7 FY09	Year -8 FY10	Year -9 FY11	Year -10 FY12	Year -11 FY13	Year -12 FY14	Year -13 FY15	Year -14 FY16	Year -15 FY17	Year -16 FY18	Year - 17 FY19	Year -18 FY20	Year -19 FY21	Remaining Project Life	Current 3 year Request
Maintenance Inspection											$3,796	$3,895	$3,996	$4,100	$4,206	$4,316	$4,428	$4,543	$4,661	$4,782	$42,724	$11,687
General Maintenance																					$0	$0
Surveys																					$0	$0
Sign Replacement															$14,000						$14,000	$0
Federal S&A																					$0	$0
Maintenance/Rehabilitation																					$0	$0
E&D																					$0	$0
Construction																					$0	$0
Construction Oversight																					$0	$0
Total					$0	$0	$0	$0	$0	$0	$3,796	$3,895	$3,996	$4,100	$18,206	$4,316	$4,428	$4,543	$4,661	$4,782	$56,724	$11,687

O&M Expenditures from COE Report	$116,582
State O&M Expenditures not submitted for in-kind credit	$0
Federal Sponsor MIPRs (if applicable)	$0
Total Estimated O&M Expenditures (as of April 2010)	$116,582

Current O&M Budget less COE Admin	$225,211
Remaining Available O&M Budget	$108,629
Incremental Funding Request Amount FY12-FY14	**-$96,942**

Current Project Life Budget less COE Admin	$225,211
Total Projected Project Life Budget	$173,306
Project Life Budget Request Amount	**-$51,905**

Appendix C
(Field Inspection Notes)

MAINTENANCE INSPECTION REPORT CHECK SHEET

Project No. / Name: **PO-06 Fritchie Marsh**

Date of Inspection: ____6/21/12___ Time: __10:00am__

Structure No. _______n/a____________________

Inspector(s):_Richard, Blanchard, James

Structure Description: **HWY 90 Culvert & Salt Bayou Bulkhead**

Water Level Inside:___N/A_____ Outside: __N/A_____

Type of Inspection: Annual

Weather Conditions: __Warm, Clear_______________________

Item	Condition	Pysical Damage	Corrosion	Photo #	Observations and Remarks
Steel Bulkhead / Caps	Good	None	None	1	
Handrails, Grating, Hardware, etc.	Good	None	None	1	Vegetation and debris surrounding railings. Overall condition is good.
Signage, Supports	Good	None	None	1	Clear and legible.
Rock RipRap channel lining	Good	None	None	n/a	
W-14 Weir structure	Good	None	None	1	Submerged.
W-14 diversion channel dredge	Good	n/a	n/a	2	Sunken branches at inlet of channel
Salt Bayou dredging	n/a	n/a	n/a	n/a	A thorough inspection was not conducted at this time.
72" Diameter culvert	Good	None	None	4	Functioning properly. No undermining of the structure observed.
HWY 90 road surface	Good	None	None	n/a	